Matching Probabilities: The Behavioral Law and Economics of Repeated Behavior

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Individuals often repeatedly face a choice of whether to obey a particular legal rule. Conventional legal scholarship assumes that whether such a choice is made repeatedly or is a one-time event has no effect on individuals' decisions. In either case, individuals are expected to maximize their payoffs. Experimental studies, however, suggest that individuals facing a recurring choice, in contrast to individuals making the choice only once, do not behave as maximizers. Instead, individuals facing the choice repeatedly apply the strategy of “probability matching.” For example, individuals failed to maximize when presented with a die with four red faces and two white faces, and asked to predict the colors of a series of rolls. Although maximization demands consistently betting on the red, individuals preferred a “mixed” approach; red was chosen in 2/3 of the rolls and white in 1/3 of the rolls.

This Article presents several normative and descriptive applications that probability matching has in the legal context. Normatively, it shows how probability matching affects optimal investment in law enforcement. Descriptively, it suggests that probability matching provides a new rationale for existing legal doctrines, such as the imposition of punitive damages on repeated wrongdoers, the imposition of harsher sanctions on recidivists, and rules attributing liability for the mere infliction of risks. This Article thus shows that experimental findings corroborate the intuition that law ought to, and in fact does, differentiate sharply between repeated and single-instance behavior.

Individuals often repeatedly face a choice of whether to obey a particular legal rule. A driver parking her car on the street needs to decide every morning whether to pay the required parking fee; a polluter must routinely choose whether to comply with the relevant environmental regulations; a grocer must choose repeatedly whether or not to report her gains to the tax authorities.
Conventional legal scholarship has long assumed that whether such choices are made repeatedly or on a one-time basis is expected to have little or no effect on individuals' decisions. Following models of rational choice theory, traditional legal analysis predicts that, in either case, individuals would form their choices in a way that maximizes their payoff. Whether required to decide routinely or only once, rational individuals are assumed to obey the law whenever the benefit from breaching the law is outweighed by the expected cost.

A large body of experimental literature, however, suggests that individuals facing a recurring choice do not behave as predicted by the conventional rationality assumption. As this literature demonstrates, when a choice involving probabilistic outcomes is presented repeatedly, individuals tend to decide suboptimally. Rather than maximizing their payoff, individuals under such circumstances often follow the strategy of "probability matching."

A representative demonstration of the "probability matching" phenomenon was illustrated by Charles Gallistel.1 In Gallistel's experiment, a number of Yale students and a rat were pitted against each other. The rat was first trained to run a T-shaped maze with a feeder at the end of each branch. In each trial only one of the feeders was "armed." If the rat chose the armed feeder, it got a pellet of food. If it chose the unarmed feeder, the trial ended with the rat receiving nothing. Above each feeder was a light, which turned on when the feeder was armed. The students could see the light, but the rat could not. Finally, the experiment was designed so that on a randomly chosen 75 percent of the trials, the feeder in the left branch was armed; in the other 25 percent, the feeder in the right branch was armed.

After allowing the students to observe the relative probabilities over a number of rounds, the students were asked to predict before every trial which light—right or left—would turn on. Thus, like the rat, they had to make a choice between two probabilistic outcomes, where one outcome was three times as likely as the other. Because the food was allocated randomly, the strategy that maximized success was to always choose the left side—the more frequently armed feeder. To choose the right side was to opt for the side that pays off only 25 percent of the time in preference to the side that pays off 75 percent of the time. The results showed that the rat, rather quickly, followed the optimizing strategy; in almost all trials it chose the left feeder. The undergraduates, by contrast, almost never chose the high payoff side exclusively. More specifically, the students "matched" the relative fre-

1  Charles R. Gallistel, The Organization of Learning 351–52 (MIT 1990) (providing a comprehensive examination of several models and characteristics of learning).
quency of their choices to the relative frequencies that the sides were armed. On average, the students choose the left side approximately 75 percent of the time.\(^2\)

Probability matching has been observed in a series of studies, under different experimental settings, and despite efforts to induce individuals to behave as mandated by rational choice theory.\(^3\) This Article investigates the relevance of probability matching to law enforcement policies as well as to legal doctrine. It demonstrates that probability matching may affect the optimal level of investment in law enforcement. It also suggests that probability matching may provide a new rationale for the prevalent use of “escalating sanctions,” both in tort and in criminal law. Last, the Article also explains how probability matching accounts for the design of different liability systems.

Part I provides the theoretical background. It presents the large body of experimental scholarship concerning probability matching and surveys some attempts to explain this phenomenon. Part II analyzes the relevance of probability matching to law enforcement. In particular, it demonstrates that an optimal enforcement system aimed at regulating recurring activities ought to take into account the behavior predicted by probability matching. The last two Parts demonstrate how probability matching can provide a rationale for various legal rules and doctrines. Part III shows that probability matching can explain the practice of imposing harsher sanctions for repeated misconduct both in the context of torts (by imposing punitive damages on those who repeatedly perform wrongs) and in the context of criminal law (by imposing harsher sanctions on recidivists). As the analysis illustrates, both legal practices produce the necessary incentives for individuals most likely to behave as probability matchers. Part IV shows how probability matching may affect the design of different liability regimes. In particular, probability matching shows the advantages of using a risk-based liability system (imposing costs on the creation of risks) rather than the use of a harm-based liability system (imposing costs only for the creation of risks that materialize in harm).

Conventional scholarship is often accused of ignoring reality and positing unrealistic assumptions.\(^4\) This Article is part of a growing at-

\(^2\) Id at 352.

\(^3\) The first experiments demonstrating probability matching were conducted in the early 1950s. Since then new experiments have been designed that corroborated the early results and extended them. For a recent review of the literature, see, for example, David R. Shanks, Richard J. Tunney, and John D. McCarthy, A Re-examination of Probability Matching and Rational Choice, 15 J Beh Dec Making 233, 233–35 (2002). See also note 11.

\(^4\) See, for example, Russell B. Korobkin and Thomas S. Ulen, Law and Behavioral Science: Removing the Rationality Assumption from Law and Economics, 88 Cal L Rev 1051, 1056–58 (2000) (criticizing law and economics and demonstrating the relevance of behavioral sciences in
tempt by legal scholars to exploit the findings of social sciences when designing legal rules and providing new rationales for existing legal doctrines. This Article demonstrates that the intuition that law ought to differentiate sharply between repeated misconduct and single-instance misconduct can be rationalized and grounded in the findings of the experimental literature.

I. PROBABILITY MATCHING: THEORETICAL BACKGROUND

Studies conducted both by psychologists and economists show that probability matching is a persistent phenomenon, occurring under different experimental settings. Part I.A describes these studies. Part I.B discusses the possible explanations for this apparently irrational behavior.

A. Experimental Studies

Assume a die with four red faces and two white faces. You are told that the die will be rolled 100 times. You are also told that if you correctly predict the color of each roll, you will receive a reward—$10 for a correct “red” guess and $10 for a correct “white” guess. What would one do under these circumstances? What ought one to do under these circumstances?

The “maximization rule”—the rule that maximizes the expected value of awards—would require participants to choose the red color in all 100 rolls. Yet participants in such a game who were asked to

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evaluate alternative strategies often preferred a “mixed” approach.\(^6\) According to this strategy, bets are divided so that red is chosen in \(2/3\) of the rolls and white in \(1/3\) of the rolls. Choosing red in all 100 rolls produces, on average, 66.6 correct “red” guesses. The “mixed” approach, in contrast, provides 44.4 correct red guesses \((2/3 \times 2/3 \times 100)\) and 11.1 correct white guesses \((1/3 \times 1/3 \times 100)\), for a total of only 55.5 correct guesses. Psychologists and economists have labeled this phenomenon “probability matching.”\(^7\) Probability matching can be defined as the tendency to adopt a mixed strategy dictated by the relative frequency of events, even when the utility-maximizing strategy would be to always behave in a way that presupposes that the most probable event would occur.\(^8\)

Probability matching suggests that there is a difference between the behavior of participants in a single-shot decision and in cases involving a recurring decision. In a single roll of a die with four red faces

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\(^6\) For studies reporting such results, see Richard F. West and Keith E. Stanovich, *Is Probability Matching Smart? Associations Between Probabilistic Choices and Cognitive Ability*, 31 Memory & Cognition 243, 244–45 (2003) (finding that most college students participating in a die-rolling experiment rejected the maximization rule and instead applied the strategy of probability matching); Iddo Gal and Jonathan Baron, *Understanding Repeated Simple Choices*, 2 Thinking & Reasoning 81, 93–96 (1996) (reporting that a substantial number of participants did not opt for the maximization rule); Cameron R. Peterson and Z.J. Ulehla, *Sequential Patterns and Maximizing*, 69 J Exp Psych 1, 2–3 (1965) (showing that although motivated by real money awards for correct guesses, only five out of twenty individuals consistently guessed “red”).

\(^7\) Probability matching should not be confused with the “gambler’s fallacy” phenomenon. The gambler’s fallacy refers to the tendency of individuals to assume that the odds for an event with a fixed probability increase or decrease depending upon recent occurrences. The gambler’s fallacy deals with individuals’ predictions concerning a single event. For example, given six consecutive heads, the gambler’s fallacy induces individuals to predict the next toss of the coin would be a tail. In contrast, probability matching refers to the predictions individuals will make given a series of events. Probability matching experiments have indicated that individuals’ tendency to “match” probabilities occurs even where participants manifest no tendency for the gambler’s fallacy. See, for example, M.P. Friedman, et al, *Two-Choice Behavior Under Extended Training with Shifting Probabilities of Reinforcement*, in R.C. Atkinson, ed, *Studies in Mathematical Psychology* 250, 290 (Stanford 1964) (analyzing participants’ choices in a probability matching experiment and finding the absence of any “negative recency effect,” that is, the gambler’s fallacy). See also Lee Roy Beach and Richard G. Swenson, *Instructions about Randomness and Run Dependency in Two-Choice Learning*, 75 J Exp Psych 279, 280 (1967) (demonstrating the phenomenon of probability matching in an experiment where participants were explicitly instructed to “ignore the runs and to avoid the gambler’s fallacy”).

\(^8\) The fact that participants fail to maximize their payoffs in the repeated choice scenarios has attracted the attention of rational choice theorists. Kenneth Arrow, for example, noted that “[w]e have here an experimental situation which is essentially of an economic nature in the sense of seeking to achieve a maximum of expected reward, and yet the individual does not in fact, at any point, even in a limit, reach the optimal behavior.” Kenneth J. Arrow, *Utilities, Attitudes, Choices: A Review Note*, 26 Econometrica 1, 14 (1958) (describing the results of an experiment where individuals are asked to predict an event the occurrence of which is random with a constant probability). For a recent critique of the phenomenon from the perspective of rational choice, see Nir Vulkan, *An Economist’s Perspective on Probability Matching*, 14 J Econ Surv 101, 113–14 (2000).
and two white faces, individuals consistently pick the red color. In contrast, when presented with a recurring decision involving many rolls of the die, participants do not simply make decisions as if each game is independent. Instead, their guesses are guided by the ratio of relevant probabilities and, consequently, they adopt a mixed strategy. Put differently, while in a one-shot game with a binary choice individuals will maximize their prospects of success, in repeated choice scenarios they will behave in a suboptimal manner.9

Probability matching has been extensively documented in the experimental literature.10 Several dozen experiments have shown that participants consistently deviate from the maximization rule.11 In one of the classic experiments, duplicated many times, participants observed a long series of flashing lights, some of them green and others red. The flashing lights appeared on the screen randomly, but such that 70 percent of the flashing lights were green and 30 percent red. At the

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9 This difference in individuals’ behavior patterns was recently illustrated by Michael Birnbaum and Sandra Wakcher. In their study, Birnbaum and Wakcher showed participants several hundred simulations of races involving two horses. One horse was proven to be more successful, although the other horse prevailed occasionally. Subsequently, participants were asked to predict which of the two horses was likely to win in each of the next 100 races. Results indicated that most participants did not bet consistently on the more “successful” horse, but rather followed the strategy of probability matching. In contrast, when asked to make one final prediction concerning the last race, almost all participants chose the “successful” horse. See Michael H. Birnbaum and Sandra V. Wakcher, Web-based Experiments Controlled by JavaScript: An Example from Probability Learning, 34 Beh Rsrch Methods, Instruments, & Computers 189, 196 (2002).


11 For an overview of the literature, see Jerome L. Myers, Probability Learning and Sequence Learning, in W.K. Estes, ed, 3 Handbook of Learning and Cognitive Process: Approaches to Human Learning and Motivation 171, 172-84 (Lawrence Erlbaum 1976). While probability matching has been extensively documented, several studies have indicated that it may decrease (although not disappear) under some circumstances. It was shown, for example, that after a very large number of trials, some individuals’ asymptomatic performance exceeds the results predicted by probability matching. High monetary rewards/fines for correct/incorrect guesses were also shown to induce some individuals to perform better. See Vulkan, 14 J Econ Surv at 106-11 (cited in note 8). Nevertheless, “while instructional and motivational manipulation can yield increased probability of predicting the more frequent event, subjects consistently fall short of the optimal strategy of always predicting that event.” Myers, Probability Learning and Sequence Learning at 177. In fact, in some studies, monetary payoffs caused participants to perform worse than participants who did not play for real money. For experiments in which participants performed suboptimally despite monetary payoffs and a large number of trials, see Shanks, Tunney, and McCarthy, 15 J Beh Dec Making at 234 (cited in note 3) (concluding that the experimental literature shows that “even under monetary payoffs” participants failed to maximize and “continue[d] to forfeit payoffs”); Anthony Patt, Understanding Uncertainty: Forecasting Seasonal Climate for Farmers in Zimbabwe, 6 Risk, Dec & Policy 105, 111-14 (2001) (conducting an experiment demonstrating individuals’ tendency to match probabilities even when the payoff for correct guesses was very large); Daniel Friedman and Dominic W. Massaro, Understanding Variability in Binary and Continuous Choice, 5 Psychonomic Bull & Rev 370, 386 (1998) (showing that “changing the decision treatment from score to score + pay did not reliably” improve performance).
end of an initial session in which the lights were shown, participants were asked to guess the color of each of the next 100 flashing lights. Consistent with the probability matching phenomenon, 70 percent of the time participants predicted that the next flashing light would be green, and 30 percent of the time that it would be red. Participants were capable of observing the probability of the appearance of the lights, but failed to pursue the optimal strategy—the strategy most likely to maximize their payoffs. Instead of always choosing green and thus guessing correctly in 70 percent of cases, they adjusted their answers to the relative frequency of the events. Experiments have also indicated that probability matching similarly occurs when the outcomes are not binary (red or green), and include more than just two choices. Experiments employing three choices, for example, showed that individuals fail to maximize and generally match their choices to the relevant probabilities.12

Studies indicate that participants apply probability matching for gains as well as for losses. For example, in one version of the flashing lights experiment, participants were given monetary rewards for every correct guess. In another form of the experiment, participants were granted a certain amount of money as an endowment, and a fine was imposed for every incorrect answer. The results showed that, in both instances, individuals correctly observed the probability of each color, but failed to adopt the rule that maximized their prospects of guessing correctly. Instead, participants consistently followed the probability matching strategy. Similarly, experiments involving both rewards for correct guesses and penalties for incorrect guesses have indicated that participants acted as probability matchers.13 Finally, the distribution of probabilities was also found to have no bearing on the participants’ behavior. It proved to be insignificant whether the proportion between green and red lights was 90 percent to 10 percent or 60 percent to 40 percent. In all cases, participants failed to maximize; their prediction of

12 See Myers, *Probability Learning and Sequence Learning* at 173–74 (cited in note 11) (summarizing the results of several studies involving three or more probabilistic outcomes).

13 For an example, see Yoella Bereby-Meyer and Ido Erev, *On Learning to Become a Successful Loser: A Comparison of Alternative Abstractions of Learning Processes in the Loss Domain*, 42 J Math Psych 266, 277–79 (1998). Bereby-Meyer and Erev conducted three similar experiments differing only in the payoff given for correct and incorrect guesses. Id. In the first experiment, participants were given four Israeli cents for a correct guess (and no penalty for an incorrect guess). In the second experiment, two cents were given for a correct guess and a penalty of two cents for an incorrect guess. Finally, in the third experiment, a penalty of four cents for an incorrect guess was the only payoff. In all three variations participants failed to maximize by opting exclusively for the more frequent outcome. See id at 278–79. See also Patrick Suppes and Richard C. Atkinson, *Markov Learning Models for Multiperson Interactions* 197–98 (Stanford 1960) (reporting individuals’ suboptimal behavior in a probability matching experiment involving monetary awards and penalties for correct and incorrect guesses).
the subsequent flashings corresponded to the observed probability of each color.\textsuperscript{14}

Additional experiments show that individuals react in a similar manner when confronted with asymmetrical payoffs. In such cases, the rates at which participants choose each option correspond to the expected gain. Rather than simply following the probability of each event, participants also adjust for the different payoffs.\textsuperscript{15}

In a study conducted by Ward Edwards, participants were asked to predict which of two lights ("left" or "right") would be turned on in a game involving multiple rounds.\textsuperscript{16} Participants were awarded real money for every correct guess, yet payoffs were asymmetric. The reward for a correct "right" guess was three times the reward for a correct "left" guess (twelve cents and four cents, respectively). Analysis of the last fifty rounds—after participants had observed and learned the relevant probabilities—showed that participants "matched" their guesses, while taking into account the different rewards.\textsuperscript{17} For example, in one version of the experiment, the probability that each light would appear was equal (that is, each light was on in 50 percent of the cases). Although maximization required opting consistently for the "right"

\textsuperscript{14} See Jerome L. Myers, et al, \textit{Differential Memory Gains and Losses and Event Probability in a Two-Choice Situation}, 66 J Exp Psych 521 (1963) (observing the application of probability matching when the distribution of the probabilities for the two binary options was 60 percent versus 40 percent); W.K. Estes and J.H. Strughan, \textit{Analysis of a Verbal Conditioning Situation in Terms of Statistical Learning Theory}, 47 J Exp Psych 225, 228–29, 234 (1954) (reporting the use of probability matching in experiments in which probability distribution was rather extreme, that is, low probability for the less frequent option (15 percent) and high probability (85 percent) for the more frequent option). For a recent experiment demonstrating the effect of probability matching for a range of probabilities, see Michael H. Birnbaum, \textit{Online Studies of Probability Learning 3–5}, online at http://psych.fullerton.edu/mbrinbaum/papers/probLearn5.doc (visited Sept 19, 2005) (varying randomly the probability between zero and one).

\textsuperscript{15} This behavior pattern is often labeled "matching law," which is expressed by the following equation:

$$\frac{b_1}{b_2} = \frac{E(V_1)}{E(V_2)}$$

where $b_1$ indicates the frequency of behavior one, $b_2$ indicates the frequency of behavior two, and $E(V_1)$ and $E(V_2)$ indicate the expected value for behavior one and two, respectively. See, for example, Louis N. Gray, Mark C. Stafford, and Irving Tallman, \textit{Rewards and Punishments in Complex Human Choices}, 54 Soc Psych Q 318, 318–20 (1991) (building on the "matching law" literature to propose a refined model that includes both benefits and costs).


\textsuperscript{17} Edwards's study involved several experimental groups, differing in the information and type of feedback given to the participants. None of the groups, however, applied the maximization rule, although some participants performed somewhat better than predicted by probability matching. Id at 180–83. The results to which we refer above are those of the group under the typical conditions of probability matching experiments, namely, a repeated choice involving two binary, independent options (group "OL"). Id.
guess—considering its higher payoff—participants adopted a mixed approach. Following the expected reward for each guess, participants distributed their guesses in a 3:1 ratio. For every three “right” guesses, they entered one “left.” Other studies provided similar results.

Signal detection and prediction of die rolling are rather artificial environments. Additional studies have illustrated the effect of the probability matching phenomenon in more natural settings, representing more realistic everyday dilemmas. For example, in a series of studies, participants were asked to assume the role of medical practitioners making a series of diagnoses. Participants initially learned the correlation between certain symptoms and the likelihood of a disease. Subsequently, participants were presented with the description of the symptoms of several patients and were requested to make as many correct diagnoses as possible. To maximize the probability of correct diagnoses, participants should have consistently chosen the outcome (disease/not disease) more frequently associated with that particular symptom pattern. Participants, however, made judgments that were guided by the ratio of probabilities. In one study, for example, one particular symptom pattern predicted a disease with 78 percent probability. To maximize the probability of correct diagnoses, participants should have diagnosed any person with the relevant symptoms as suffering from this disease. Yet participants in this experiment attributed the disease to only 75 percent of the cases involving these symptoms.

18 Id. Suboptimal patterns were observed for different probability ratios. For example, with these same payoffs, when the ratio between the “left” and “right” was set to 70 percent and 30 percent respectively, participants chose “left” roughly 47 percent of the time. Such a rate corresponds to the relative expected payoff for each guess (70% x 2 = 1.4 cents, 30% x 6 = 1.8 cents). Suboptimal behavior was also observed when the ratio for the “left” light was increased to 80 percent and 90 percent. Id.

19 For example, in Patt’s study—composed of several experiments—individuals were shown a rotating wheel with a stationary arrow in the middle. The wheel had parts in green and red. Before each spin of the wheel, participants were requested to guess to which color the arrow would eventually point. In the first experiment, the wheel had equal “red” and “green” parts. The payoff for a correct “red” guess and a correct “green” guess was $2 and $3, respectively. Although maximization requires guessing exclusively “green,” participants chose green only 55 percent of the time and red 45 percent of the time. In the second experiment, the wheel was three-quarters “red” and one-quarter “green.” The payoffs for correct “red” and “green” guesses remained $2 and $3, respectively. As such, expected payoff for a “red” guess was $1.50 (0.75 x $2), compared to only $0.75 (0.25 x $3) for a “green” guess. Despite these values, participants mixed their guesses. Matching the expected payoff from each guess, participants chose “red” only 66 percent of the time and “green” 34 percent of the time. See Patt, 6 Risk, Dec & Policy at 111, 113–14 (cited in note 11).


21 See David R. Shanks, A Connectionist Account of Base-rate Biases in Categorization, 3 Connection Sci 143, 155–56 (1991) (showing that participants failed to maximize the number of correct diagnoses).
A recent experiment conducted by Alexandra Kincannon provides an illustration of the effect of probability matching in a legal context. In Kincannon's experiment, participants were asked to guess which of two parking lots—each containing several illegally parked cars—would be ticketed. In each trial, only one of the parking lots was ticketed. The experiment was designed so that the first lot was randomly ticketed 75 percent of the time, while the other only 25 percent of the time. After observing and learning the probabilities associated with each parking lot for 100 trials, participants were requested to guess, in each of the next 50 trials, which of the lots would be ticketed. The results showed that participants did not follow the maximization rule. Rather than consistently choosing the first lot, participants “matched” their guesses. Participants, on average, chose the first lot roughly 75 percent of the time.

The robustness of the probability matching phenomenon is further indicated by its occurrence even when participants have been cued about the correct strategy to pursue. Although encouraged to apply the maximization rule, participants have nonetheless continued to manifest a strong tendency to follow the strategy of probability matching. Two studies provide illustrative examples.

In an experiment conducted by Hal Arkes, Robyn Dawes, and Caryn Christensen, participants were presented with what was purportedly a partial sample of a student’s transcript. Each such transcript comprised three grades, chosen randomly from the courses in

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23 The experiment involved two experimental groups. In addition to guessing which parking lot would be ticketed, one experimental group was required to complete a secondary task that required “working memory resources.” This procedure was followed to examine whether individuals with greater cognitive ability perform better on probability matching experiments. The results showed that indeed individuals required to complete the two tasks simultaneously performed worse than those required to only guess which parking lot would be ticketed. In the first experimental group, participants chose the first lot roughly 80 percent of the time; in the second experimental group, participants chose the first lot 70 percent of the time. These results suggest that “analytic processing resources are needed to use the maximizing strategy.” Kincannon, The Roles of Context and Working Memory in Probability Matching (cited in note 22). Both groups, however, substantially failed to maximize.

24 Hal R. Arkes, Robyn M. Dawes, and Caryn Christensen, Factors Influencing the Use of a Decision Rule in a Probabilistic Task, 37 Org Beh & Hum Dec Processes 93, 93 (1986) (assessing possible strategies aimed at incentivizing participants in a probabilistic task to use a “decision rule” that will “enable . . . them to choose correctly on a large proportion (70%) of judgment tasks”).
which the student took part. Based on these reported grades, participants were asked to predict whether or not that student had graduated with honors. Participants were also provided with a “helpful hint.” According to the hint, only students whose sample transcript included two or three As were “likely to have graduated with honors.” To motivate maximization, participants were explicitly informed that the “helpful hint” leads to correct predictions in 70 percent of the cases, and that 70 percent is “about as well as people can do.”

The experiment results showed that participants failed to optimize their guesses. Rather than guessing “honors” only when the sample transcript included two or three As, participants instead applied a “mixed” strategy, opting occasionally for the less probable possibility given the student’s grades. Furthermore, Arkes, Dawes, and Christensen found that providing monetary payoff for every correct answer, and even warning the participants that “people who try to do better than 70% on this task actually do a lot worse” did not cause participants to apply the maximization rule.

A recent study conducted by Edmund Fantino and Ali Esfandiari, involving a version of the flashing lights experiment, further indicates that additional types of cues or combinations of such cues do not lead

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25 Id at 96–97.
26 Id at 97.
27 Id. The actual percentages of “honors” for groups with zero, one, two or three As were 20, 40, 60 and 80, respectively. Accordingly, as explained to the participants, guessing “honors” only when the sample transcript included two or three As ensured a hit rate of 70 percent. Use of the “hint” was thus the only way (other than sheer luck) to perform well on the experiment.
28 Id at 99–100. As participants were shown forty transcripts, twenty-eight (70 percent) was the optimal score. In practice, most experimental groups scored twenty or less. Id at 98–101. Other experiments have provided similar results. Studies by Braveman and Fischer and by McCracken, Osterhout, and Voss have demonstrated that informing participants that the sequence is random or that it is impossible to be correct on every trial did not result in maximization. See Norman S. Braveman and Gloria J. Fischer, Instructionally Induced Strategy and Sequential Information in Probability Learning, 76 J Exp Psych 674, 675–76 (1968); J. McCracken, C. Osterhaut, and James F. Voss, Effects of Instructions in Probability Learning, 64 J Exp Psych 267, 270–71 (1962). Despite these instructions, most participants matched the probabilities. See Braveman and Fischer, 76 J Exp Psych at 675–76; McCracken, Osterhaut, and Voss, 64 J Exp Psych at 270–71.
29 Arkes, Dawes, and Christensen, 37 Org Beh & Hum Dec Processes at 97 (cited in note 24). Arkes, Dawes, and Christensen’s experiment involved one control and three experimental groups. The first experimental group (“innovative group”) was encouraged “to surpass” the 70 percent level of performance by using its “keen perception”; the second group (“debiasing group”) was warned that abandoning the rule of maximization would drastically detract from its performance; the third group (“no feedback”) was provided no feedback until the end of the experiment. Id at 95, 97. Another variable was the presence or absence of monetary incentives for accurate judgments. The results of the different groups indicated that almost all participants failed to follow the maximization rule. The only group that approximated optimization was the “debiasing” group under the “no reward” condition. Id at 96–101.
to efficient behavior. For example, to provide an incentive for participants to opt consistently for the more probable event, some participants were instructed that winning the game requires guessing correctly only 75 percent of the time. During the initial session, blue lights were shown 75 percent of the time and green lights 25 percent of the time. Nevertheless, participants continued to adopt a mixed strategy. For every several blues, participants occasionally guessed green. The experiment’s results showed that providing such a cue had, in practice, little effect. Both participants who were so instructed and those who were not deviated from the maximization rule equally. On average, participants in both groups chose blue (the frequent event) in roughly 80 percent of the trials.

Like Arkes, Dawes, and Christensen, Fantino and Esfandiari have similarly found that even explicitly informing the participants of the exact probabilities and cuing them about the best strategy to pursue did not lead participants to adopt the maximization rule. Other means used by Fantino and Esfandiari to obtain maximization likewise showed no or limited effect. According to Fantino and Esfandiari, “the most compelling conclusion warranted by the present data is that subjects’ decision making in this task is not optimal.”

In sum, the experimental literature indicates that probability matching is a robust phenomenon. As illustrated by numerous studies, probability matching applies to a broad distribution of probabilities, to gains as well as to losses, and to different types of payoffs. Probability

30 Fantino and Esfandiari, 56 Can J Exp Psych at 59 (cited in note 10) (exploring “additional variables that might affect the degree of probability matching, especially as a function of being told the optimal score”).
31 Id at 60.
32 Id at 62 (concluding that “optimal behaviour did not occur whether or not subjects were given [the maximization-incentivizing] instructions”).
33 Id at 60.
34 Id at 60, 62 (“Optimal behaviour did not occur whether or not subjects were given [instructions that they could be correct on no more than 75 percent of trials].”). See also Birnbaum and Wakcher, 34 Beh Rsch Methods, Instruments, & Computers at 197 (cited in note 9) (concluding from their results that despite “explicit instructions concerning the optimal strategy, accompanied by information about the probability of events . . . [participants’] performance still falls well short of optimal behavior”). For another well-known experiment, see Richard C. Nies, Effects of Probable Outcome Information on Two-Choice Learning, 64 J Exp Psych 430, 432 (1962) (reporting that providing participants the exact probability for each possible outcome made only four of the 192 participants opt for the optimal strategy of always predicting the more likely event).
35 To encourage maximization, some participants received extra payoffs for correct answers, others were motivated by formatting the experiment as a competition, and some were also requested to recommend the best strategy to other participants. Most groups’ average rate of choosing the frequent event was within the range of 80 to 90 percent. Neither group maximized. Fantino and Esfandiari, 56 Can J Exp Psych at 60 (cited in note 10).
36 Id at 62.
matching is detected not only in artificial environments but also in settings approximating real world decisions. Finally, even when actively encouraged to maximize, individuals continue to apply the strategy of probability matching.

B. Accounting for the Probability Matching Phenomenon

Why do people prefer the probability matching strategy to the maximization rule? Researchers have proposed two principal theories. First, individuals facing pure probabilistic outcomes often mistakenly believe that they have identified a pattern according to which outcomes occur. Consequently, "[s]o long as the subject believes that some correct sequence will produce errorless performance, the fact that one stimulus is reinforced more than the other is irrelevant and has no effect on subsequent choices."3

While this explanation attributes probability matching to a cognitive misconception, other scholars have suggested that probability matching is often a rational behavior. Although suboptimal in some contexts, scholars have shown that, in other contexts, probability matching is an optimizing strategy. Under this theory, therefore, probability matching achieves maximization in many cases.


Studies involving probabilistic outcomes have shown that individuals search for patterns even when such patterns are manifestly absent.36 Probability matching may thus reflect individuals' false conviction that purely probabilistic outcomes obey a certain predictable order.37 Some probability matching experiments provide direct support for this hypothesis.

For example, in Richard Nies's study, participants were requested to predict in each trial which color marble—red or blue—would roll out of a box containing seventy blue and thirty red marbles.38 Following the other experiments demonstrating probability matching, the

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37 Robert W. Weisberg, Memory, Thought and Behavior 304 (Oxford 1980) (indicating that prior information or experience may cause subjects to fail to solve probabilistic outcome problems).

38 See Jonathan Baron, Thinking and Deciding 81 (Cambridge 1994) (explaining that the suboptimal behavior documented in probability matching experiments is due to the general tendency of individuals to "look for hypotheses" (deterministic sequences) in probabilistic environments).

39 See, for example, Myers, Probability Learning and Sequence Learning at 184 (cited in note 11) (concluding that probability matching results indicate the "propensity of subjects to seek sequential cues and to incorporate such information into their decision making process"); Merrill M. Flood, Environmental Non-Stationarity in a Sequential Decision-Making Experiment, in Mark R. Thrall, ed, Decision Process 287, 288 (Wiley 1954) (arguing that probability matching occurs because subjects believe they can identify a predictable sequence).

results showed that participants strongly deviated from maximization. Although participants were shown that the outcomes were utterly random, forty-three out of ninety-six participants admitted in a post-experiment questionnaire that they were “looking for a pattern.”

In John Yellott’s study, the experiment was manipulated to include two stages. The first stage was the traditional probability matching experiment, in which participants had to predict which of two lights would appear. The more frequent event appeared in 80 percent of the trials. Participants matched their predictions to this frequency, and failed to optimize. In the second stage, rather than randomization, the researcher deliberately turned on the light that was chosen by the participant, guaranteeing a 100 percent hit rate. Nonetheless, participants continued, in 80 percent of the cases, to choose the light that had appeared more frequently in the first stage. As argued by later researchers, these results suggest that “subjects had been seeking causal sequences throughout the experiment and were misled into thinking that they had finally succeeded.”

Finally, the fact that both young children and animals tend to perform better than human adults in probability matching experiments lends further support to this explanation. As it appears, children and animals do better “because they are not as hindered by the tendency to search for and posit causal hypotheses.”

2. Heuristics.

Probability matching experiments typically involve uncorrelated payoffs. The size of participants’ reward for every correct answer is independent of the other participants’ reward. Yet, in many real life contexts, individuals compete for scarce resources. Some scholars have argued that probability matching can, under these circumstances, be a

41 Id at 432.
44 For studies indicating that children of young age tend to apply the maximization rule rather than probability matching, see, for example, Peter L. Derks and Marianne I. Paclisanu, Simple Strategies in Binary Prediction by Children and Adults, 73 J Exp Psych 278, 284 (1967) (finding that increased age correlates with increased disposition to match probabilities but also with increased “ability to utilize sequential information”); Mary Helen Jones and Shephard Liverant, Effects of Age Differences on Choice Behavior, 31 Child Dev 673, 680 (1960) (finding that nursery school children were more likely than elementary school children to engage in maximizing behavior).
45 George Wolford, Michael B. Miller, and Michael Gazzaniga, The Left Hemisphere's Role in Hypothesis Formation, 20 RC64 J Neurosci 1, 1 (2000) (finding that “split-brain” individuals probability match when using their left hemisphere, but approach maximization with their right hemisphere).
rational strategy. \(^{46}\) Using insights from game theory, it has been shown that opting for the less frequent event can be rational in competitive environments with multiple agents. Because it is expected that most participants will choose the more frequent event, this payoff will be distributed among many. In contrast, choosing the less frequent event promises the decisionmaker the whole payoff, undivided, when it materializes. \(^{47}\)

Consider, for example, the case of individuals competing for limited food resources. If all individuals choose the spot where previous experience suggests food is to be found in abundance, then each may get only a small share. In contrast:

The one mutant organism that sometimes chooses the spot with less food would be better off. Natural selection will favor those exceptional individuals who sometimes choose the less attractive alternative. Thus, maximizing is not always an evolutionarily stable strategy in situations of competition among individuals. Given certain assumptions, probability matching may in fact be an evolutionarily stable strategy, one that does not tend to create conditions that select against it. \(^{48}\)

Probability matching strategy can therefore be understood as a simple heuristic device, appropriate to many of the environments in which individuals interact. \(^{49}\) Some environments, however, are not competitive. In such environments, application of the maximization rule would have produced better results.

II. PROBABILITY MATCHING AND LAW ENFORCEMENT

The preceding Part presented the broad experimental literature concerning the probability matching phenomenon. This Part explores the effect probability matching may have in the legal context. Part II.A specifically illustrates the importance that probability matching has in the design of an optimal law enforcement system. Part II.B discusses the relevance of this analysis to the actual world.

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\(^{46}\) See, for example, Gerd Gigerenzer, *Adaptive Thinking: Rationality in the Real World* 204-06 (Oxford 2000) (arguing that while the maximization rule is inefficient in social isolation, probability matching can be the optimal strategy in many contexts involving social interaction).

\(^{47}\) See Gallistel, *The Organization of Learning* at 352-53 (cited in note 1).

\(^{48}\) Gigerenzer, *Adaptive Thinking* at 206 (cited in note 46).

\(^{49}\) This argument is in line with many other studies showing that people "make judgments about probability on the basis of heuristic devices, responsive perhaps to high costs of inquiry and decision, that work in many cases but that tend also to lead to systematic errors." Cass R. Sunstein, *Behavioral Analysis of Law*, 64 U Chi L Rev 1175, 1187 (1997).
A. Law Enforcement Policymaking

Probability matching studies suggest that individuals facing a repeated choice involving probabilistic costs or benefits often behave as "probability matchers" rather than as "maximizers." Probabilistic costs are characteristic of law enforcement. Because it is impossible to place a police officer next to every stop sign or to inspect each potentially polluting individual, the imposition of criminal sanctions is inevitably probabilistic. Probabilistic costs likewise characterize tort law; even when detection is certain, it is often the case that the actual infliction of harm is probabilistic.

Potential criminal-related behaviors and tort-related activities are often also of a repetitive nature. Drivers repeatedly face the choice of whether to illegally cross the same intersection, and polluters repeatedly face the choice of whether to pollute. As such, probability matching has important implications concerning optimal law enforcement policy. This Part is devoted to examining the ways in which probability matching can improve policymaking in the context of criminal law and tort law.

To illustrate, consider the following example. Assume that the police wish to deter drivers from crossing an intersection illegally. The only sanction for crossing the intersection illegally is $100, and the benefit of crossing it illegally without being caught is also $100. Assume, in addition, that drivers cross the intersection repeatedly. Finally, assume that a police car can be placed such that drivers who cross the intersection cannot see it in advance. Thus, the drivers' behavior is determined solely by the sanction and by the subjective probability they attribute to the placing of the police car in the intersection.

Under the predictions of conventional legal analysis, if drivers are risk neutral, it is sufficient to place the police car at the intersection in 51 percent of the cases (or at least to make drivers believe that it is there 51 percent of the time). This guarantees that it would be irrational to cross the intersection illegally since the expected costs of crossing illegally are higher than the expected benefits. Placing the car at the intersection less than 51 percent of the time is wasteful be-

50 It may be argued that, in the real world, under less sterile conditions, individuals do not treat repeated choices as part of one sequence. We address this concern later. See text accompanying note 63.
51 Similarity of payoffs is assumed for arithmetic convenience. When payoffs are not equal, probability matching follows the "matching law." See note 15 and accompanying text.
52 The benefit from crossing the intersection illegally, if not caught, is $100. If the police officer is placed at the intersection 51 percent of the time, the expected benefit is $49 ((100% - 51%) x $100). The sanction for illegally crossing the intersection, if caught, is $100. If the police officer is placed at the intersection 51 percent of the time, the expected cost is $51 (51% x $100). Thus, placing the police officer at the intersection 51 percent of the time makes it unprofitable for the drivers to illegally cross the intersection.
cause drivers would never stop; placing the car more than 51 percent of the time is also wasteful since the same deterrence can be achieved with less investment.

Probability matching suggests otherwise. Placing the police car at the intersection 51 percent of the time would cause drivers to cross the intersection legally in roughly 51 percent of the cases. Increasing the presence of the police car to 70 percent of the time would therefore increase law-abiding behavior. If the differential cost of placing the police car at the intersection 70 percent rather than 51 percent of the time is sufficiently low, it may be desirable on the part of the police to make this investment.

To illustrate the relevance of probability matching to optimal investment in law enforcement, consider the following case. Assume that 500 vehicles cross the intersection every day. Assume that a car illegally crossing the intersection imposes an expected social cost of $1. Finally, assume that the marginal costs of placing a police officer in the intersection increase as shown in the following table:

<table>
<thead>
<tr>
<th>Days on Which a Police Officer is Placed at the Intersection</th>
<th>Marginal Enforcement Costs</th>
<th>Total Enforcement Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>First day</td>
<td>$100</td>
<td>$100</td>
</tr>
<tr>
<td>Second day</td>
<td>$400</td>
<td>$500</td>
</tr>
<tr>
<td>Third day</td>
<td>$1500</td>
<td>$2000</td>
</tr>
<tr>
<td>Fourth day</td>
<td>$3000</td>
<td>$5000</td>
</tr>
</tbody>
</table>

Conventional legal analysis would suggest, under these circumstances, that it is inefficient (assuming risk-neutral drivers) to place a police officer at the intersection. As drivers’ expected costs from crossing the intersection illegally are equal to their expected benefit, they will cross the intersection illegally unless it is more likely than not that

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53 This result, as predicted by probability matching, is based on the assumption that individuals are risk neutral. Once risk aversion is taken into account, the prediction would be different and would be determined both by attitudes to risk as well as by probability matching.

54 Increasing the presence of the police in the intersection can be achieved either by requiring police officers to work more or by recruiting additional personnel. Under both alternatives the marginal cost of enforcement is likely to increase. Additional working hours demands paying police officers overtime; additional personnel requires both recruiting individuals with higher opportunity costs and significant investment in their training. See, for example, Henrik Lando and Steven Shavell, *The Advantage of Focusing Law Enforcement Effort*, 24 Intl Rev L & Econ 209, 216 (2004) (arguing that “for a variety of reasons, it will often be difficult for the number of enforcement agents to be increased at a constant cost,” and at least in the short run the marginal cost of additional enforcement is increasing); Joshua C. LaGrange, *Note, Law, Economics and Drugs: Problems with Legalization Under a Federal System*, 100 Colum L Rev 505, 515 (2000) (claiming that “the marginal cost of enforcement is increasing”).
they will be caught. Therefore, deterrence will be achieved only if a police officer is placed at the intersection at least four days a week (more than 50 percent of the time). In weekly terms, this would indeed save $3500 in social costs (7 × $500), but would require investing $5000 ($100 + $400 + $1500 + $3000) in enforcement. Any attempt to place a police officer less than four days would be a waste of money, as drivers would not be deterred from crossing the intersection illegally.

In contrast, if people are "probability matchers," placing a police officer at the intersection for two days would be efficient. Every day that a policeman is placed deters 500 vehicles from crossing the intersection illegally, saving $500 in social costs. Drivers, noting that the police officer is present one-seventh of the time, will obey the light at the same rate, that is, one day a week. Given that the costs of placing a police officer for the first and second day are each lower than $500, a policymaker ought to place a police officer in the intersection for two days. This example illustrates that a policymaker relying on the predictions of probability matching may invest more in enforcement than a policymaker relying on the predictions of conventional legal analysis.55

In the last example it was assumed that social costs produced by criminal behavior (crossing the intersection illegally) remain fixed for every illegal act. In some contexts, however, the marginal social cost generated by illegal behavior is expected to increase with additional levels of the activity. Under such conditions, even if one assumes that marginal enforcement costs are fixed, probability matching may again recommend a different policy than that mandated by conventional legal scholarship.

Consider, for example, the case of pollution. Assume that the marginal social harm increases with every additional unit of contamination. While one unit of pollution is harmless, the second unit causes a harm of $100, the third unit causes a harm of $200, and so forth. To illustrate, assume that there is an individual who produces the same unit of pollution each day, seven days a week. Assume also that the only sanction for each instance of illegal pollution is $100 and that the individual gains $100 from each instance of pollution. Finally, assume that the cost of employing a detection team to identify pollution is $550 a day. The following table describes marginal and total social costs resulting from pollution.

<table>
<thead>
<tr>
<th>Day</th>
<th>Marginal Social Cost</th>
<th>Total Social Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$100</td>
<td>$100</td>
</tr>
<tr>
<td>2</td>
<td>$200</td>
<td>$300</td>
</tr>
<tr>
<td>3</td>
<td>$300</td>
<td>$400</td>
</tr>
<tr>
<td>4</td>
<td>$400</td>
<td>$500</td>
</tr>
<tr>
<td>5</td>
<td>$500</td>
<td>$600</td>
</tr>
<tr>
<td>6</td>
<td>$600</td>
<td>$700</td>
</tr>
<tr>
<td>7</td>
<td>$700</td>
<td>$800</td>
</tr>
</tbody>
</table>

55 A small alteration of the assumptions can also illustrate that probability matching can justify a lesser investment in enforcement. Assume that the expected social cost of a car crossing the intersection illegally is $2 rather than only $1. Traditional legal analysis, under this condition, supports the placement of the police officer at the intersection. Placing the police officer for four days a week would deter drivers from crossing the intersection illegally. It would save $7000 ($500 × 2 × 7) in social costs, outweighing enforcement costs ($5000). Probability matching, however, indicates that the police officer should be placed for only two days. Because enforcement costs of the third and fourth days are $1500 and $3000 respectively, such enforcement is inefficient given that the social cost saved for each day is only $1000 (2 × $500).
The Behavioral Law and Economics of Repeated Behavior

Table 2

<table>
<thead>
<tr>
<th>Instances of Pollution per Week</th>
<th>Marginal Social Costs</th>
<th>Total Social Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>2</td>
<td>$100</td>
<td>$100</td>
</tr>
<tr>
<td>3</td>
<td>$200</td>
<td>$300</td>
</tr>
<tr>
<td>4</td>
<td>$300</td>
<td>$600</td>
</tr>
<tr>
<td>5</td>
<td>$400</td>
<td>$1000</td>
</tr>
<tr>
<td>6</td>
<td>$500</td>
<td>$1500</td>
</tr>
<tr>
<td>7</td>
<td>$600</td>
<td>$2100</td>
</tr>
</tbody>
</table>

Under these circumstances, traditional legal scholarship would recommend no enforcement. Because the benefit to the individual from pollution is equal to his cost, this individual would pollute only if it is more likely than not that he would not be caught. Deterrence, therefore, would be achieved only if a detection team is employed at least four days a week. In weekly terms, operating the detection unit saves $2100 in social costs, but would require investing $2200 ($550 × 4) in enforcement. Any attempt to employ the detection unit for less than four days would be a waste of money, as the individual would not be deterred from polluting.

Probability matching, in contrast, mandates operating the detection unit once a week. Such a level of enforcement is expected to induce the individual to refrain from polluting one out of every seven times; the individual would pollute only six times rather than seven. Consequently, $600 would be saved, which outweighs the enforcement costs ($550).  

A small change in the assumptions can illustrate that probability matching may also justify a smaller investment in enforcement than that demanded by conventional analysis. Assume that the marginal social costs of pollution increase more rapidly, so that the first unit of pollution is harmless, the second unit causes harm of $150 (rather than $100), the third unit causes harm of $300 (rather than $200), and so forth. The following table summarizes the social costs resulting from pollution under this modified assumption.

<table>
<thead>
<tr>
<th>Instances of Pollution per Week</th>
<th>Marginal Social Costs</th>
<th>Total Social Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>2</td>
<td>$150</td>
<td>$150</td>
</tr>
<tr>
<td>3</td>
<td>$300</td>
<td>$450</td>
</tr>
<tr>
<td>4</td>
<td>$450</td>
<td>$900</td>
</tr>
<tr>
<td>5</td>
<td>$600</td>
<td>$1500</td>
</tr>
<tr>
<td>6</td>
<td>$750</td>
<td>$2250</td>
</tr>
<tr>
<td>7</td>
<td>$900</td>
<td>$3150</td>
</tr>
</tbody>
</table>

Traditional legal scholarship, under this condition, supports the employment of the detection unit. Operating the detection unit for four days would deter the individual from polluting. Con-
To conclude, the preceding analysis demonstrates that if either the marginal costs of enforcement or the marginal costs of illegal activity (or both) are not constant, probability matching and traditional cost-benefit analysis dictate different enforcement policies. Differences may cut both ways: probability matching may justify higher as well as lower investment in enforcement than suggested by traditional legal scholarship.

B. Probability Matching and Actual Legal Contexts

The analysis in Part II.A demonstrates the effect that probability matching may have on optimal law enforcement policymaking. There are several factors, however, that may limit the impact of probability matching in actual legal contexts. This Part investigates these factors, and suggests that probability matching is nevertheless relevant to the design of enforcement.

Arguably, the “real world” differs in several respects from laboratory environments. First, in contrast to laboratory experiments, in the real world individuals are not always aware of the probabilities of detection or the severity of the sanctions. It is possible that probability matching does not occur in contexts involving significant uncertainty. Second, legal contexts may involve cases in which the probability that the cost or benefit will materialize is small. In contrast, most of the probability matching experiments involved probabilities of intermediate size. Studies have shown that individuals misconceive the likelihood of events with small probabilities. It is unclear whether probability matching also occurs in this range of probabilities. Third, the experiments involved a repetitive set of choices, iterated many times in a very short period. As the results show, individuals lump their decisions together as if these choices are part of one sequence of events. It is unclear whether people in the real world, under less sterile circumstances, perceive their decisions as part of one sequence. Fourth, in the actual world, individuals may possess insurance. Insurance eliminates the probabilistic nature of costs and consequently it eliminates the sequentially, $3150 in social costs would be saved, which outweighs enforcement costs ($550 \times 4 = \$2200$). Probability matching, however, indicates that the detection unit should be employed for only three days. Individuals will now pollute only four days per week, leading to a savings of $2250 (\$900 + \$750 + \$600)$ in social costs at a price of $2200$. Employing the detection unit for a fourth day costs $550, but would save only $450 in social costs.

57 See, for example, Massimo Piattelli-Palmarini, Inevitable Illusions: How Mistakes of Reason Rule Our Minds 130–32 (Wiley 1994) (Massimo Piattelli-Palmarini and Keith Botsford, trans) (reviewing studies showing individuals’ tendency to overreact to small risks, while—at the very far extreme of the probability scale—they tend to ignore probabilities completely).
circumstances necessary for probability matching. Fifth, as the experiments of probability matching involved only individuals, it is unclear whether corporations also behave as probability matchers. These are important concerns that may limit the applicability of probability matching or may suggest that further experimental research is required. Even so, the existing data concerning probability matching suggests that it does have significant real-world predictive power.

First, as long as individuals have subjective convictions concerning the probability or size of sanctions, experiments indicate that they will act as probability matchers. In most of the experiments described above, participants were not explicitly told the probabilities of the events. Probability matching thus occurred despite a degree of uncertainty with respect to the probabilities. Similarly, in the legal context, the absence of explicit information regarding the probabilities of detection should not diminish the relevance of probability matching.

Second, as stated earlier, the distribution of probabilities was found to have no bearing on study participants' behavior. These studies demonstrate that probability matching occurs irrespective of changes in the relevant probabilities. Moreover, data show that at least in some contexts individuals face significant probabilities of being detected and convicted. The experiments described above are directly relevant to these contexts. Even if most criminals committing a particular crime are indeed subjected to low probabilities, certain classes of criminals, such as repeat offenders, are subject to higher probabilities of detection—arguably similar to those examined in the probability matching experiments. Additional experiments are required in order to determine whether probability matching occurs in contexts involving small probabilities.

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58 It is possible that probability matching may influence individuals' incentives to purchase insurance in the first place. As no data yet exist on this point, additional research would be required to determine the exact effects.

59 For a policymaker, individuals' high degree of uncertainty with respect to the relevant probabilities may disrupt the possibility to regulate their behavior. If individuals are repeat players, however, they are more likely to develop accurate beliefs concerning the relevant probabilities.

60 See text accompanying note 14.

61 See, for example, Stephen Craig Pirrong, The Self-Regulation of Commodity Exchanges: The Case of Market Manipulation, 38 J L & Econ 141, 197 (1995) (arguing that detection of market power manipulations is "very high"); Mark A. Cohen and David T. Scheffman, The Antitrust Sentencing Guideline: Is the Punishment Worth the Costs?, 27 Am Crim L Rev 331, 349 (1989) (showing that, at least for some crimes, the probability of detection is much higher than conventionally assumed and ranges from one in three to one in four).

62 See, for example, David A. Dana, Rethinking the Puzzle of Escalating Penalties for Repeat Offenders, 110 Yale L J 733, 742-53 (2001) (suggesting that at least in some contexts repeat offenders are subjected to higher probabilities of detection).
Third, some experiments involved realistic settings in which participants were presented with the repetitive choices not only in one condensed session but over longer periods. For example, in one study participants played for eight days with long breaks between each experimental session. The results show that probability matching occurred under these circumstances, suggesting that participants indeed considered these decisions not in isolation but rather as part of one sequence. Such circumstances approximate real life legal contexts.

Fourth, insurance is not available against most criminal sanctions and, even when insurance is available, not all individuals are fully insured against all types of tort or other forms of noncriminal liability. Moreover, even when insurance exists, it is often the case that the insured is required to pay some amount as a copayment.

Fifth, more research is admittedly needed in order to examine the applicability of probability matching to corporations. Existing data, however, provide some evidence suggesting that corporations are also subject to cognitive biases, possibly including the tendency to match probabilities. A number of studies show that suboptimal behaviors can also be identified among corporate managers and personnel. Some of these behaviors stem directly from failures to assess or correctly perceive probabilistic outcomes.

63 See, for example, Edwards, 52 J Exp Psych at 170–73 (cited in note 16) (reporting probability matching in an experiment consisting of daily sessions, with long separating intervals). See also Friedman, et al, Two-Choice Behavior at 290 (cited in note 7) (documenting probability matching in an experiment consisting of three separate daily sessions). Moreover, if probability matching is not a cognitive misconception but rather a heuristic device, such behavior is expected in real life contexts. Although in most cases it will maximize individuals' payoff, in other contexts such a strategy will be suboptimal. See text accompanying notes 46–47.

64 Liability insurers typically exclude coverage for injury or damage intentionally caused by the insured. See Robert H. Jerry II, Understanding Insurance Law 479 (Matthew Bender 3d ed 2002). In addition, policies generally exclude "criminal acts." The criminal acts exclusion is broader because it affects even unintentional crimes. See, for example, Daniel C. Eidsmoe and Pamela K. Edwards, Home Liability Coverage: Does the Criminal Acts Exclusion Work Where the "Expected or Intended" Exclusion Failed?, 5 Conn Ins L J 707, 718 (1998–99) ([I]t is clear that the criminal acts exclusion is intentionally broader in scope than the expected or intended language. The criminal acts exclusion excludes coverage for unintentional, as well as intentional criminal acts."). See also Allstate Insurance Co v Norris, 795 F Supp 272, 273 (SD Ind 1992) (upholding an exclusion of coverage for criminally reckless acts).

Finally, empirical data indicate the prevalence of probability matching outside the laboratory. Several researchers have linked individuals’ suboptimal behaviors observed in reality with the strategy of probability matching. For example, it has been shown that some adolescent subjects believe “they should wear seatbelts most of the time” because the belts are generally helpful “but can sometimes cause harm.”

Empirical research regarding the conduct of professional physicians provides another illustration. A number of studies have indicated that doctors often fail to maximize when required to form their diagnoses based on patients’ symptoms. Rather than consistently opting for the more probable diagnosis, physicians appear to apply different personal decisionmaking methods that result in a substantially fewer number of correct diagnoses. Even when explicitly shown otherwise, studies indicated that physicians tend to believe they can somehow outperform the maximization rule. Additional research has found similar behavior with respect to other professionals. Although aware of the probabilities, accountants, psychologists, and others who were given relevant information and required to form their judgment have been shown to occasionally predict the less probable outcome. Moreover, although statistical methods have been shown consistently to be capable of bringing substantial improvements in the accuracy of repetitive diagnostic decisions, professionals continue to use a subjective, clinical judgment approach when making predictive decisions.

Admittedly, in practice, a law enforcement system that aims at achieving optimal results by taking into account the effect of probability matching might face complex informational hurdles. Consider again the traffic example. Roads might be used simultaneously by frequent drivers as well as drivers who use the road only occasionally. Thus, only some of the drivers are expected to behave as probability matchers. Calculating the optimal investment in law enforcement requires identification of the relative number of drivers belonging to each one of

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66 See Gal and Baron, 2 Thinking and Reasoning at 82 (cited in note 6).
67 See Arkes, Dawes, and Christensen, 37 Org Beh & Hum Dec Processes at 108 (cited in note 24) (reviewing several studies examining doctors’ strategies in forming medical diagnoses based on patients’ conditions).
68 Id.
69 Id.
70 For an overview of the literature, see William M. Grove and Paul E. Meehl, Comparative Efficiency of Informal (Subjective, Impressionistic) and Formal (Mechanical, Algorithmic) Prediction Procedures: The Clinical-Statistical Controversy, 2 Psych, Pub Policy & L 293, 293-95 (1996) (documenting the major studies since 1928 that examine the predictive abilities of professionals).
71 See, for example, John A. Swets, Robyn M. Dawes, and John Monahan, Psychological Science Can Improve Diagnostic Decisions, 1 Psychological Sci in the Pub Int 1, 20-23 (2000) (discussing the benefits of statistical prediction rules as well as the major reasons that clinicians resist using them).
these groups. Although this information is sometimes available, at other times the costs involved in finding this information might be prohibitive.\footnote{ Such information can be obtained rather easily, for example, on toll highways. With the increase in drivers' use of devices such as EZ-Pass, information concerning the identity of drivers using the road can be obtained without substantial cost. See, for example, the recent discussion (from Aug 18, 2003) in the California Senate, suggesting that information on drivers' use of EZ-Pass and similar devices offers the State data on the identities of road users. \textit{RFID Technology and Pervasive Computing}, Informational Hearing of the California Senate Subcommittee on New Technologies, August 18, 2003, online at http://www.sen.ca.gov/ftp/sen/committee/standing/energy/_home/archive_hearings_2003-2004/8-18-03transcript.htm (visited Sept 19, 2005).}

Adjusting investment in law enforcement to account for individuals' tendency to use probability matching is one way the law may achieve efficient deterrence. Another possibility is to use a flexible regime of sanctions, sensitive to the effects of probability matching. Unlike ex ante law enforcement, information concerning the frequency of individuals' behavior is often available at the time of the imposition of the sanctions. The use of flexible sanctions, however, mandates that the legal system differentiate between wrongdoing that is part of a sequence of misconduct and wrongdoing that is committed only sporadically. The next Part shows that both punitive damages in torts and escalating penalties in criminal law often serve as mechanisms to achieve such a differentiation. Both regimes provide the necessary incentives to deter those individuals most likely to behave as probability matchers.

III. ESCALATING SANCTIONS

Individuals who repeatedly engage in misconduct are often subjected to augmented sanctions. The following analysis suggests that this legal practice can eliminate, to a large extent, the inefficiencies resulting from the phenomenon of probability matching. Such a legal regime provides the necessary level of deterrence, both for individuals who are expected to act as probability matchers and for those who are likely to behave as maximizers.

Part III.A investigates the treatment of repeated misconduct in tort law and shows that punitive damages have historically been associated with repeated misconduct. Part III.B, which discusses the use of escalating penalties for repeat offenders, demonstrates the prevalence of this practice in the criminal context.

A. Punitive Damages

Courts have traditionally imposed overcompensatory damages on defendants who act on a repetitive basis. The following paragraph,
taken from a century-old decision of a Georgia court, provides an illustrative example. In its decision to award punitive damages to a plaintiff whose crops were harmed by sparks from railroad locomotives, the Georgia court stated that:

We can suppose other negligent acts by a defendant for a single tort, which, while not subjecting him to punitive damages, might by frequent repetition . . . make him liable for punitive damages. For instance, if A. and B. pass each other daily, and A. negligently stumbles against B. and injures him, A. would only be liable to B. for B.'s actual damages. But if, every time they meet, or every other time, or once a week, or once a month, A. should negligently stumble against B. and injure him, would not this constant repetition of A.'s tort raise a jury question as to whether B. was entitled to punitive damages to deter A. from continuing his negligence? Suppose, again, that A., when passing on his regular daily route by B.'s premises, should carelessly and negligently throw a lighted cigarette, or cigar-stump, on B.'s lawn, and thereby injure and burn B.'s grass and flowers; A. would be liable for actual damages only; but if this occurred fifteen times within two years should not B. be allowed punitive damages to deter A. from continuing his careless and tortious conduct?  

This ruling is repeated in numerous other cases. These cases indicate that the frequency of the wrong has been regarded as an important consideration in the decision to award punitive damages.

Although the law concerning punitive damages has evolved, the conviction that the repeated occurrence of the misconduct provides justification for awarding punitive damages has been reasserted and reaffirmed by contemporary decisions, as well as by contemporary

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73 Charleston & Western Carolina Railway Co v McElmurray, 16 Ga App 504, 85 SE 804, 808–09 (1915).
74 For early decisions holding that punitive damages should be imposed when the defendant's tortious behavior is recurring, see, for example, Gila Water Co v Gila Land & Cattle Co, 30 Ariz 569, 249 P 751, 754–55 (1926) (stating that "repeated diversions of plaintiff's water, preventing it from carrying on its farming," justify the award of "exemplary damages"); Sorg v Fredrick, 255 Pa 617, 100 A 481, 483 (1917) (holding that the lower court was justified in awarding punitive damages when there was evidence of "repeated wrongful acts" on the part of defendants); Detroit Daily Post Co v McArthur, 16 Mich 447, 455 (1868) (holding that repeated instances of libel justify the imposition of "increased damages").
75 For the development of the punitive damages doctrine, see Thomas B. Colby, Beyond the Multiple Punishment Problem: Punitive Damages as Punishment for Individual, Private Wrongs, 87 Minn L Rev 583, 614–29 (2003) (tracing the imposition of punitive damages from medieval England to twentieth century America).
76 See, for example, Pulla v Amoco Oil Co, 72 F3d 648, 659–60 (8th Cir 1995) (justifying its decision to reverse the award of punitive damages on the grounds that "[i]n the instant case, there is no evidence or indication that [the misconduct] reflected a company policy or practice
commentators. More recently, the Supreme Court has had two opportunities to address the conditions for the imposition of punitive damages, and both cases highlighted the relevance of a prior "pattern of misconduct" as a relevant consideration. Finally, the relevance of repetitive misconduct has been recognized by state legislation. State laws often explicitly condition the imposition of punitive damages on the defendant’s recurring behavior.

This practice, however, cannot be explained by the conventional rationales purporting to justify the practice of punitive damages. Legal scholarship has suggested two principal explanations—based on either deterrence or retribution—why it might be justifiable to charge the defendant more than the harm she actually caused. Neither, however, seems to account for this long-established practice of awarding punitive damages in cases of repeated misconduct.

The first justification connects the practice of punitive damages to the problem of insufficient deterrence. Concerned with cases in
which the plaintiff may not sue, legal scholars (especially in the law and economics tradition) have suggested that punitive damages serve to deter tortfeasors in contexts in which underenforcement is expected. Under this first explanation, punitive damages are needed to supplement compensatory damages when the latter are not sufficient to provide optimal incentives to tortfeasors. Scholars have provided several reasons why, in the absence of punitive damages, injurers may be underdeterred. First, victims may not be aware of or may have difficulty proving some of the necessary elements of the wrong. Second, even when the plaintiff is aware of all of the necessary facts and possesses evidence to support her claim, the costs of litigation might be prohibitive. Finally, a special relationship, such as when the plaintiff is the employee or the patient of the defendant, may discourage her from suing. Imposing punitive damages in the limited cases where suits are filed serves to compensate for the cases in which they are not.

This explanation, however, fails to justify the rule that repeated misconduct is an important consideration in awarding punitive damages. There is no reason to believe that the probability of escaping liability is higher in cases of repeated misconduct in comparison to cases in which the defendant acts only once. The opposite may be true: it is possible that repeated misconduct would inevitably be detected and would lead to a successful award of compensatory damages. Likewise, it is possible that a single, nonrepeated negligent act would have a high probability of escaping liability. Without empirical evidence suggesting otherwise, it seems that the chance of the commence-

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81 For an elaborate discussion, see A. Mitchell Polinsky and Steven Shavell, *Punitive Damages: An Economic Analysis*, 111 Harv L Rev 869 (1998) (arguing that punitive damages are necessary when there is a significant likelihood that the wrongdoer will escape liability). Some courts have explicitly embraced this rationale. See, for example, *BMW*, 517 US at 582 (“A higher ratio [of punitive to compensatory damages] may . . . be justified in cases in which the injury is hard to detect.”); *Perez v Z Frank Oldsmobile, Inc*, 223 F3d 617, 621 (7th Cir 2000) (“Frauds often escape detection, and the need to augment deterrence of concealable offenses is a principal justification of punitive damages.”); *Circolo v City of New York*, 216 F3d 236, 245 (2d Cir 2000) (“Such a [multiplier] conception of punitive damages, again, is not new, and it has been recognized by courts as well as scholars.”); *Zazú Designs v L’Oréal SA*, 979 F2d 499, 508 (7th Cir 1992) (“Punitive damages are appropriate when some wrongful conduct evades detection; a multiplier then both compensates and deters.”).

82 See Polinsky and Shavell, 111 Harv L Rev at 888 (cited in note 81) (discussing reasons why wrongdoers escape liability, thus necessitating the imposition of punitive damages). See also Steven Shavell, *Foundations of Economic Analysis of Law* 244–45 (Harvard 2004) (discussing reasons why damage awards must exceed losses in order to effectively deter wrongdoers); Sharkey, 113 Yale L J at 366–67 (cited in note 80) (discussing reasons for tort plaintiffs' underenforcement).

83 To their credit, Polinsky and Shavell concede that their model cannot explain existing doctrine. Their suggestion is aimed at initiating reconsideration of existing doctrine rather than explaining it. See Polinsky and Shavell, 111 Harv L Rev at 896–900 (cited in note 81).
Empirical studies as well as courts' decisions indicate that punitive damages are often imposed as a result of a strong ethical sentiment. Overcompensatory damages reflect the jury's or judge's moral condemnation with regard to the behavior of the defendant. Under this second, nonconsequentialist explanation for punitive damages, the conventional requirement for recurring conduct seems logical. An individual who is repeatedly engaged in harm-causing behavior appears more reprehensible than an individual who only occasionally injures others.

The recent decision of the Supreme Court in *State Farm Mutual Auto Insurance Co v Campbell,* however, seems to require more than just a clear indication concerning the defendant's moral fault. As the Court explained, for the purpose of imposing punitive damages, repeat behavior must be composed of "similar" acts, with each act "repli[cat[ing] the prior transgressions." A plaintiff would not be awarded punitive damages simply because the defendant committed a series of wrongs, unless the wrongs are sufficiently similar to each other. A plaintiff showing that the defendant was involved in a series of wrong-

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84 For some other, less-discussed, economic rationales for awarding punitive damages, see Shavell, *Foundations of Economic Analysis of Law* at 245–47 (cited in note 82). None of these explanations, however, are relevant to the issue at stake.

85 For an early case stating that reprehensible conduct justifies overcompensatory damages, see, for example, *Day v Woodworth,* 54 US 363, 371 (1851) ("It is a well-established principle of the common law, that . . . a jury may inflict what are called exemplary, punitive, or vindictive damages upon a defendant, having in view the enormity of his offence rather than the measure of compensation to the plaintiff."). Several experimental studies show that some believe punitive damages should be restricted to instances in which the behavior of the defendant was outrageous. See, for example, Cass R. Sunstein, et al, *Predictably Incoherent Judgments,* 54 Stan L Rev 1153 (2002) (reporting the results of a number of experiments in which mock juries imposed punitive damages when the conduct of the defendant was reprehensible, but not when underenforcement was evident); Cass R. Sunstein, David Schkade, and Daniel Kahneman, *Do People Want Optimal Deterrence?* 29 J Legal Stud 237 (2000) (observing that individuals do not impose higher damage awards in hypothetical cases where detection is less likely and do not support administrative and judicial policies that seek to increase penalties in response to the probabilities of detection).

86 As far as instances of intentional torts are concerned, repeated behavior clearly reflects morally blameworthy behavior. In cases, however, in which the defendant appears only negligent, the moral reprehensibility argument is less straightforward. Even so, recurring acts of negligence may indicate that the defendant's acts are not truly innocent. See Amelia J. Toy, *Statutory Punitive Damage Caps and the Profit Motive: An Economic Perspective,* 40 Emory L J 303, 338 (1991) ("It may be that repeated misconduct speaks to the issue of the defendant's intent, since a pattern of wrongful acts might indicate that the defendant has not made a mistake.").


88 Id at 423. For an earlier decision of the Court reciting the "similarity" requirement, see *Pacific Mutual Life Insurance Co v Haslip,* 499 US 1, 21–22 (1991) (explaining that "the existence and frequency of similar past conduct" should be an important factor in courts' decisions to impose punitive damages).
ful behaviors, but such that are not clearly similar, would not be entitled to punitive damages.

This requirement that the wrongs be similar to each other is inconsistent with the rationale based on the moral condemnation of the defendant. Although a defendant who repeatedly engages in misconduct of different types might well be more reprehensible than a defendant who repeatedly engages in misconduct of one type, punitive damages will be imposed exclusively on the latter.89 Reprehensibility, therefore, cannot explain why courts differentiate between the case in which the defendant committed a series of wrongs that are different, and cases in which the defendant committed a series of wrongs that are similar.

Probability matching, in contrast, can suggest at least a partial explanation for the differentiation between these two cases. It provides a deterrence-motivated rationale, but one that is unrelated to the conventional underenforcement explanation. While the latter focuses on the plaintiff—and ties punitive damages to cases in which he will not sue—probability matching focuses on the defendant. Punitive damages might be necessary in cases in which defendants are likely to behave as probability matchers.

For illustration, consider an activity that causes harm 60 percent of the time. When harm does not occur, the benefit to the defendant is $100. When the harm materializes, the defendant derives no benefit and the damage from the activity to the plaintiff is likewise $100. Setting damages to the actual harm ($100) is enough to deter risk-neutral individuals who face a one-time opportunity to perform the activity. As the expected costs outweigh the benefit from the activity, a rational individual would avoid the activity. If individuals face the choice repeatedly, however, such a remedy would be insufficient. The tendency to "match the probabilities" would cause such individuals to adopt a mixed approach. More particularly, under these circumstances, individuals would perform the risky activity four out of ten times. Imposing substantial punitive damages on repeat tortfeasors serves to counterbalance the effect caused by probability matching. Because the expected costs become very high, such defendants will avoid the activity.90

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What State Farm did do is clarify under what circumstances "other acts" evidence is constitutionally relevant and permissible in determining whether punitive damages should be awarded and, if so, in what amount. The touchstone of using "other acts" evidence is the similarity of those acts to the conduct that specifically harmed or threatened the plaintiff.

90 Consider, for example, the expected behavior of the defendant if she is required to pay $100,000 (rather than only $100) when damage materializes. As the experimental literature
This rationale can also explain why defendants who engage in repeated misconduct that is not of a similar type should not be subjected to punitive damages. Probability matching occurs when people regard a series of discrete acts as part of one sequence. Such a perception is expected only if the individuals face a similar choice. A defendant involved in a series of unrelated wrongs is not likely to behave as a probability matcher. Such a defendant is expected to be deterred by ordinary compensatory damages.

To be sure, different cases in which punitive damages were awarded indicate that the award of punitive damages serves several purposes. This Part, however, suggests that among these purposes, the award of punitive damages addresses the inefficiencies resulting from the phenomenon of probability matching. Punitive damages create a legal regime that differentiates between individuals that are expected to maximize and those who are likely to match probabilities. It enables courts to impose higher sanctions on the latter without overdeterring the former.

Probability matching may also require adjustment in the level of the criminal sanctions imposed on recidivist offenders. The next Part suggests that the widespread use of escalating penalties represents such an adjustment.

B. Escalating Criminal Sanctions

The legal system punishes repeat offenders more severely than nonrepeat offenders. An offender committing a crime twice often receives a harsher punishment than a first-time offender, and an offender committing the offense repeatedly is likely to be sanctioned even more severely. Since Gryger v Burk—in which the Supreme Court shows, when payoffs are asymmetrical, the rates at which a risk-neutral individual will choose each option are equal to the corresponding expected payoff. See note 15. Given that the defendant faces a 40 percent chance to gain $100 (40% x $100 = $40) and a 60 percent chance to pay $100,000 (60% x $100,000 = $60,000)—a ratio of 1:1500—the defendant will virtually always refrain from the tortious activity.

See, for example, Dorsey D. Ellis, Jr., Fairness and Efficiency in the Law of Punitive Damages, 56 S Cal L Rev 1, 3–12 (1982) (discussing other, less prominent, goals that punitive damages may promote, such as providing greater incentives for private law enforcement and attorney fee shifting).

See C.Y. Cyrus Chu, Sheng-cheng Hu, and Ting-yuan Huang, Punishing Repeat Offenders More Severely, 20 Intl Rev L & Econ 127, 127 (2000) (observing that punishing repeat offenders more harshly “is a generally accepted practice of almost all penal codes or sentencing guidelines”).

For the history of the doctrine in the common law, see Andrew Ashworth, Sentencing and Criminal Justice 163–65 (Butterworths 3d ed 2000) (discussing the cumulative principle of sentencing where each subsequent criminal conviction yields heavier penalties); Leon Radzinowicz and Roger Hood, Incapacitating the Habitual Criminal: The English Experience, 78 Mich L Rev 1305, 1322–26 (1980) (discussing the cumulative system of sentencing); Leon Radzinowicz and Roger Hood, Judicial Discretion and Sentencing Standards: Victorian Attempts to Solve a Peren-
rejected the claim that the imposition of harsher sanctions on recidivists unconstitutionally subjects the accused to double jeopardy—escalating sanctions have become prevalent. For a wide range of offenses and administrative violations, federal as well as state laws impose increasingly higher sanctions for violations committed repeatedly.

Legal theorists—especially those concerned with optimal deterrence—have struggled to provide justifications for escalating sanctions despite their prevalence. In fact, some theorists have provided compelling arguments against the practice of imposing escalating penalties. Most importantly, because offenders with prior violations are

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94 334 US 728 (1948).
95 Id at 732 ("The sentence as a fourth offender or habitual criminal is not to be viewed as either a new jeopardy or additional penalty for the earlier crimes. It is a stiffened penalty for the latest crime, which is considered to be an aggravated offense because a repetitive one."). For a careful examination of the constitutionality of the practice in light of later cases, see Erwin Chemerinsky, The Constitution and Punishment, 56 Stan L Rev 1049, 1072–73 (2004).
96 Under the United States Sentencing Guidelines, for example, the punishment of federal crimes, both imprisonment terms and criminal fines, are increased if a defendant has a prior record. See United States Sentencing Commission, Guidelines Manual §§ 4A1.1, 5E1.2, Ch 5 Pt A (2003). Specific statutes often also set higher penalties for repeat offenders. For example, hiring, recruiting, and referral violations under the Immigration Reform and Control Act impose a minimum fine of $250 for a first offense, $2,000 for a second offense, and $3,000 for subsequent offenses; in addition, "due consideration shall be given to . . . the history of previous violations" in setting penalties for paperwork violations. See 8 USC § 1324a(e)(4)–(5) (2000). For a detailed overview of laws applying escalating penalties, both federal and state, see Dana, 110 Yale L J at 735–36 & nn 3–4 (cited in note 62).
97 See, for example, Winand Emons, A Note on the Optimal Punishment for Repeat Offenders, 23 Int'l Rev L & Econ 253, 253 (2003) ("For the rather developed law and economics literature on optimal law enforcement escalating sanction schemes are still a puzzle."); Dana, 110 Yale L J at 737 (cited in note 62) ("For economists and law-and-economics scholars, however, the principle of escalating penalties based on offense history is puzzling."). For some attempts to rationalize the application of escalating penalties from an economic perspective, see Chu, Hu, and Huang, 20 Int'l Rev L & Econ at 134–36 (cited in note 92) (arguing that penalties should be lesser for first-time offenders and greater for repeat offenders because of the increased risk of erroneously convicting first-time offenders); A. Mitchell Polinsky and Steven Shavell, On Offense History and the Theory of Deterrence, 18 Int'l Rev L & Econ 305 (1998) (arguing that escalating penalties may be optimal insofar as they deter both initial and repeat offenders); A. Mitchell Polinsky and Daniel L. Rubinfeld, A Model of Optimal Fines for Repeat Offenders, 46 J Pub Econ 291, 303 (1991) (arguing that escalating penalties may be efficient if the probability of detection is lower for repeat offenders because of their increased experience in committing crimes). But see Moshe Burnovski and Zvi Safra, Deterrence Effects of Sequential Punishment Policies: Should Repeat Offenders Be More Severely Punished?, 14 Int'l Rev L & Econ 341 (1994) (arguing that if total punishment is held constant, then increasing the punishment for an initial violation and decreasing the punishment for subsequent violations increases total deterrence). None of these attempts, however, provides a sufficient explanation. See Emons, 23 Int'l Rev L & Econ at 254–55 (describing previous research and concluding that "[a]t the very best the literature . . . has shown that under rather special circumstances escalating penalty schemes may be optimal").
98 See Emons, 23 Int'l Rev L & Econ at 254 (cited in note 97) (concluding that the "optimal sanction scheme is decreasing rather than increasing [with] the number of offenses").
more likely than first-time offenders to be detected," scholars have claimed that "the economic model of optimal deterrence actually supports declining penalties based on offense history for some categories of offenses, rather than nonescalating or escalating penalties."\(^\text{99}\) At least in contexts where criminal sanctions are used to deter inefficient behavior rather than aimed at providing complete deterrence,\(^\text{100}\) repeat players—in light of their higher chances of being detected—ought to be subjected to more lenient rather than harsher sanctions. In such contexts, it has been argued, a regime of escalating penalties may result in overdeterrence.

Probability matching, however, may provide a rationale for the practice of escalating penalties. Individuals who face a one-time choice to commit a harm-causing activity tend, as the experiments demonstrate, to behave as maximizers. Consequently, optimal deterrence requires setting the expected penalty equal to the social harm resulting from the activity. Under such a level of deterrence, violations will occur only when the expected benefit outweighs the social cost. In contrast, individuals facing repeated opportunities to perform the activity may act as probability matchers. As such, they may occasionally choose to perform the activity even if the expected penalty is higher than the expected benefit. Therefore, an even higher penalty is required to incentivize probability matchers to refrain from violating the law when it is socially undesirable. In the absence of a scheme of escalating penalties, individuals with repeated opportunities to violate the

\(^{99}\) See Dana, 110 Yale L J at 744–54 (cite in note 62) (explaining and empirically demonstrating why individuals acting repeatedly face higher chances of being detected when violating applicable legal rules).

\(^{100}\) Id at 737. The argument provided for this conclusion is based on the standard “optimal deterrence theory,” associated with Gary Becker’s seminal article, Crime and Punishment: An Economic Approach, 76 J Polit Econ 169 (1968). Under the conventional deterrence model, two variables fix the expected penalty: the probability of detection and the magnitude of the sanction imposed on the offender once the violation is detected. The increase of either of these factors results in a higher expected penalty. Because in the optimal-deterrence model the goal is not to achieve complete deterrence but rather only deterrence of socially inefficient violations, “an optimal expected penalty should equal the harm to society of the violation, so that the prospective offender will proceed with the violation only if the gain from doing so (which is also a societal welfare gain) exceeds the social harm that will result from the violation.” Dana, 110 Yale L J at 740 (cited in note 62). As such, if the probability for detection increases, to maintain the optimal expected penalty, the size of the sanction must be reduced. Otherwise, overdeterrence is expected.

\(^{101}\) While generally assuming less than maximal deterrence, in some contexts, such as violent crimes, optimal deterrence theory supports total deterrence considering the extremely high social costs generated by such offenses. In other contexts, however, such as “environmental, safety and labor regulations,” optimal deterrence is probably less than maximal deterrence. In the latter case, as Dana explains, a legal regime with decreasing penalties is apparently more efficient. Dana, 110 Yale L J at 741–42 (cited in note 62).
law would choose to commit the illegal behavior in accordance with the predictions of probability matching.\footnote{Another possible rationale for escalating penalties might be grounded in the differential significance of social extralegal sanctions for repeat offenders and first-time offenders. Under this explanation, the deterrent effect of extralegal sanctions for first-time offenders is particularly high. This is because "once someone has been identified as (say) a convicted embezzler, he or she loses most of the 'legitimate' opportunities and associations available to people without a record." Id at 773. In contrast, an individual with prior history has little "social capital" to lose. Because social sanctions decline based on offense history, a regime of escalating legal sanctions might be necessary. Id at 773-74 (discussing the possibility of such a rationale and suggesting it can explain some, but not all, contexts in which escalating sanctions are used).}

Escalating penalties serve, therefore, the purpose of deterring both one-time offenders and probability matchers at the lowest possible cost. The legal system applies a price discriminating mechanism under which severe (and expensive) sanctions are reserved only for individuals that cannot be deterred by moderate penalties. Setting a low initial penalty serves to deter individuals facing the choice occasionally; higher sanctions are imposed only to deter individuals who face the choice repeatedly and are likely to apply a strategy of probability matching.

Applying a flexible sanctions system, like adjusting investment in law enforcement, tackles inefficiencies resulting from individuals' tendency to apply probability matching. The next Part, discussing different liability regimes, introduces a third method to overcome the deficiencies resulting from probability matching. Individuals, as the experiments demonstrate, behave as probability matchers only when faced repeatedly with a choice involving probabilistic outcomes. Although the probabilistic nature of legal liability is sometimes inevitable, in some areas it is possible to make the imposition of liability a certainty. In the latter case, probability matching would not occur. The next Part shows how a shift from a harm- to a risk-based liability system may often eliminate the probabilistic nature of legal rules. It also provides several examples of contexts in which such a shift has occurred.

\footnote{Even with respect to offenses where total deterrence is efficient (such as violent crimes) probability matching may justify a regime of escalating penalties. As initially claimed by Bentham, and later elaborated by law and economics scholars, harsh sanctions are not costless and ought to be avoided if unnecessary. First, severe penalties eliminate marginal deterrence—the incentive to substitute less for more serious crimes. Second, severe sanctions increase enforcement costs, such as costs resulting from long incarceration periods, or costs associated with collecting large fines. Severe sanctions, therefore, must be avoided if more moderate penalties can achieve a similar level of deterrence. Regimes of escalating penalties provide this result. A harsh sanction is imposed only on those who, due to their tendency to match probabilities, are not likely to be deterred by a less stringent penalty. For Jeremy Bentham's "principle of frugality," see Jeremy Bentham, An Introduction to the Principles of Morals and Legislation 169 (Athlone 1970) (J.H. Burns and H.L.A. Hart, eds). For a more comprehensive economic analysis of the advantages of moderate sanctions, see Richard A. Posner, Economic Analysis of Law 221–23 (Aspen 6th ed 2003).}
IV. LIABILITY FOR THE IMPOSITION OF RISK

Legal systems looking to deter socially-undesirable risky activities may choose among three different liability regimes. First, a legal system could impose a risk-based liability system, namely a system that imposes sanctions on those who inflict risk regardless of whether the imposition of risk resulted in actual harm. Under this system, in order to provide efficient incentives, the legal system ought to impose a sanction that would equal the expected harm of the activity. Second, a legal system could adopt a harm-based liability system, namely a system in which only those who inflict actual harm are subject to sanctions. In this case, to provide efficient incentives the legal system must impose sanctions that are equal to the harm resulting from the behavior of the wrongdoer. Last, a legal system could adopt a mixed (risk-harm) liability system under which it imposes diverse sanctions. Under such a system, those who inflicted risk that resulted in harm would be subject to different (typically harsher) sanctions than those who inflicted risk that did not result in harm.

For illustration, consider again a risky activity that generates a $100 gain in 40 percent of cases, and a $100 loss in 60 percent of cases. Making the defendant internalize the costs of her behavior can be achieved under any of these three regimes. First, the law may apply a risk-based system: under such a regime the defendant is required to pay $60 irrespective of the actual results of her behavior. Alternatively, the law may use a harm-based system: the defendant must pay full compensation ($100), but only when her activity results in actual harm. Finally, the law may apply a mixed system: under such a liability regime the defendant is required to pay whenever she acts, but compensation will vary based on the materialization of the harm. For example, when the activity does not result in harm the defendant pays $30; when harm materializes she pays $80. Under any of these three possibilities the defendant bears the costs ($60) of her behavior.

Whereas all systems apparently produce the same incentives, probability matching suggests that a harm-based system may result in underdeterrence. Assuming detection is possible whenever the defendant acts, the imposition of liability under a risk-based system is certain, as individuals are required to pay for every risk-imposing action. In contrast, under a harm-based system the actual payment is only

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104 For a comprehensive discussion, see Steven Shavell, Foundations of Economic Analysis of Law at ch 25 (cited in note 82) (differentiating between “act-based” and “harm-based” forms of liability); Ariel Porat and Alex Stein, Tort Liability Under Uncertainty ch 4 (Oxford 2001) (discussing “risk-based liability” versus “damage-based liability”).

105 Under the “mixed regime,” the defendant pays $30 in 40 percent of cases, and $80 in 60 percent of cases. The expected cost of the activity (40% × $30 + 60% × $80) is thus exactly $60.
probabilistic. While harm is sometimes inflicted and triggers payment, on other occasions the behavior entails no costs. If the defendant repeatedly faces the choice to perform the activity, under a harm-based regime, she might apply the strategy of probability matching.

As a matter of practice, different liability regimes are applied in various areas of law. Modern criminal law systems, for example, adopt either the mixed or the risk-based system. Unsuccessful attempts (that is, imposition of risk that did not materialize in harm) are now punishable in most jurisdictions. In some systems the sanctions imposed for attempts are more lenient than those imposed for the complete offense, while in other systems the same sanction is imposed in both cases. Under either system, the imposition of criminal liability does not require actual harm.

In contrast, the traditionally prevalent legal position in tort law is that liability can only be imposed when the plaintiff has sustained damage that was wrongfully inflicted by the defendant. A drunk driver, for example, driving recklessly but hurting no one, cannot be sued in tort. The mere imposition of risk is not compensable. Tort liability is manifestly a harm-based regime. Individuals involved in tort-related risky activities on a repeated basis, especially if they are not subjected to criminal sanctions, are therefore particularly prone to apply the strategy of probability matching. The next two examples, however, show that in some tort-related contexts the traditional harm-based approach has been replaced by rules endorsing risk-based liability.

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107 Although lenient criminal sanctions for incomplete crimes are not uncommon, there is an ongoing transition towards reducing the gap in the sanctions imposed for attempts and completed crimes. The Model Penal Code, for example, recommends equal punishment for both complete and incomplete crimes. See Model Penal Code Art 5 at 295 (ALI 1985) (stating that one of the major results of the Model Penal Code provisions is “to establish these inchoate crimes as offenses of comparable magnitude to the completed crimes that are their object”). See also Yoram Shachar, *The Fortuitous Gap in Law and Morality*, 6 Crim Just Ethics 12, 13 (1987) ("Punishment for attempt has slowly ... gain[ed] parity with maximum punishment in many of the common law jurisdictions, most notably in England itself and in many of the American states.") (internal citations omitted).

108 See Matthew D. Adler, *Risk, Death and Harm: The Normative Foundations of Risk Regulation*, 87 Minn L Rev 1293, 1437 (2003) (explaining that current tort law doctrine “typically does require the occurrence of death, bodily injury, property damage, or at least emotional harm, for a tort suit to go forward. Risk imposition per se is, typically, not enough”). See also Eric A. Posner and Cass R. Sunstein, *Dollars and Death*, 72 U Chi L Rev 537, 557–59 (2005) (examining the differences between tort and regulatory law and the valuation of life, and suggesting that the tort regime’s harm-based approach is insufficient to compensate harms in cases of wrongful death whereas a risk-based regime would adequately do so).
In light of the traditional harm-based paradigm of tort law, doctors who perform negligently have generally been liable only if causing actual damage. In recent years, however, in the context of medical malpractice, courts have shown greater willingness to substitute the harm-based approach with liability that is based on risk. Using doctrines such as “loss of chance” or “increased risk of harm,” courts, rather than inquiring whether doctors’ negligence causally resulted in harm, began awarding the plaintiff compensation based on the risk created by the doctors’ negligence. Because doctors’ negligence may often potentially be the reason that the patient has not recovered, the application of these doctrines transformed tort liability in these contexts from a harm-based to a risk-based regime.

This shift from the traditional harm-based approach to a risk-based approach has eliminated, to a large extent, the probabilistic nature of doctors’ liability. Under these new doctrines, physicians can expect to be sued whenever they fail to meet the standards of the profession. Admittedly, the imposition of liability might still be probabilistic because patients may not always be able to detect doctors’ negligence. But where detection is feasible, liability would be imposed with certainty.

Likewise, in the context of tortious exposure to toxic substances, an increasing number of courts have replaced the conventional harm-based approach with liability that is essentially based on the creation of risk. Using various doctrines, these courts have allowed plaintiffs to recover damages without showing actual injury. Tortfeasors, under

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109 For an overview, see Medical Malpractice: “Loss of Chance” Causality, 54 ALR 4th 10 (1987) (analyzing the state and federal cases that consider risk-based liability in medical malpractice claims).

110 See Adler, 87 Minn L Rev at 1437–38 (cited in note 108) (“Risk imposition per se is, typically, not enough. But there are a few important doctrinal exceptions .... [I]n so-called ‘loss-of-chance’ cases, some courts have imposed liability for the mere creation of a risk.”).

111 One can think of several reasons why a patient will not sue even when the detection of doctors’ negligence is likely. For example, the patient may not be aware of the possibility of suing, or she might lack the financial resources necessary for filing and handling the claim. Insurance, however, often helps to overcome these hurdles, as the insurance company becomes the plaintiff in interest.

112 See Adler, 87 Minn L Rev at 1438–39 (cited in note 108) (noting that “in the toxic tort context ... some courts do award damages to plaintiffs who have been exposed to a toxic substance and whose risk of death or disease has been increased by that exposure, but have not died and are currently asymptomatic for the diseases possibly resulting from the exposure”).

113 See Tamsen Douglass Love, Deterring Irresponsible Use and Disposal of Toxic Substances: The Case for Legislative Recognition of Increased Risk Causes of Action, 49 Vand L Rev 789, 804 (1996) (explaining that courts have developed three doctrines to deal with toxic tort issues—“medical monitoring,” “fear for future disease,” and “outright recovery for increased risk of disease”—and that “[a]ll three ... essentially allow the plaintiff to recover before it is known whether she will actually suffer a medical problem as a result of the defendant’s conduct. As such, all three are essentially causes of action for increased risk, though only one is explicitly framed in these terms”).
these doctrines, are compelled to pay all individuals who may have been harmed (or who may be harmed in the future) by the exposure to their toxic substances. Rather than paying only those who actually suffer provable injury, a defendant's liability is extended to every individual who is placed at risk by the toxic materials.\textsuperscript{114}

Medical malpractice and exposure to toxic substances are two contexts in which courts have shown willingness to impose liability for the mere infliction of risk. From a theoretical perspective, liability for risk imposition can be extended to other categories. Scholars have indeed suggested applying a similar approach in other contexts such as latent disease, labor injuries, and others.\textsuperscript{115} To the extent these suggestions will be implemented, the probabilistic nature of tort liability will be substantially diminished.

To be sure, identifying the most advantageous type of liability system in each category requires balancing several concerns. Different factors lend support to each type of regime. A harm-based system, for example, triggers less litigation, as it allows claims only when the plaintiff suffers actual damage.\textsuperscript{116} A harm-based system is also less exposed to judicial errors, at least with respect to cost-benefit evaluation of the activity. Under a risk-based system, because claims may be filed even when the risky activity did not cause any damage, courts must form their evaluation without actual evidence concerning the resulting


These claims are styled "risk-based" because they are predicated simply on exposure to a tortiously imposed risk. They seek damages without regard to formal accrual or any physical effect (manifested or not) of the ultimate major harm and loss, which is causally associated with the tortious act in question; indeed, they seek damages without regard to formal accrual—or any physical effect—of causally related minor or precursor condition.

\textsuperscript{115} For several such proposals, see, for example, Note, \textit{Latent Harms and Risk-Based Damages}, 111 Harv L Rev 1505 (1998) (considering the appropriate solution to the problem of latent harms left uncompensated by the legal system); Keith W. Lapeze, \textit{Recovery for Increased Risk of Disease in Louisiana}, 58 La L Rev 249 (1997) (analyzing potential solutions to increased risk cases under Louisiana law); Christopher H. Schroeder, \textit{Corrective Justice and Liability for Increasing Risks}, 37 UCLA L Rev 439 (1990) (arguing that the link between corrective justice and causation is not essential to the law); Note, \textit{An Analysis of the Enhanced Risk Cause of Action (Or How I Learned to Stop Worrying and Love Toxic Waste)}, 33 Vill L Rev 437 (1988) (examining the approach of the New Jersey Supreme Court to enhanced risk claims, which takes a moderate position between traditional tort principles and enhanced risk liability); Glen O. Robinson, \textit{Probabilistic Causation and Compensation for Tortious Risk}, 14 J Legal Stud 779 (1985) (examining risk-based liability by considering both the objectives of tort law and the potential problems that a risk-based system could create).

\textsuperscript{116} See Shavell, \textit{Foundations of Economic Analysis of Law} at 582 (cited in note 82) (suggesting that one disadvantage of the risk-based approach is that "the volume of cases that would have to be considered would be plausibly at least a hundred times larger than the volume" under a harm-based regime).
harm. Under a harm-based regime, where the plaintiff can sue only when harm has been inflicted, evidence concerning the harms generated by the activity is available. On the other hand, risk-based systems seem less arbitrary. Liability under these schemes does not depend on luck; all defendants with equal moral culpability are subjected to similar sanctions irrespective of the (random) results of their behavior. Effective deterrence considerations, such as taking the solvency of the perpetrator into account, may also support a risk-based approach.

Given the plurality of factors that bear on this question, the decision regarding which liability regime should be applied in a certain context might be complicated. Probability matching, however, suggests that risk-based systems are especially attractive in cases of repeated misconduct. In some cases, other relevant factors may outweigh this consideration. Yet if the activity is not likely to trigger criminal sanctions, if the concern for courts' misevaluation is unlikely, and if the volume of litigation is not prohibitive, applying a risk-based regime can overcome inefficiencies resulting from the probability matching phenomenon.

CONCLUSION

Rational choice approaches predict that individuals will consistently behave in a way that maximizes their utility. Rational choice theory attributes behavioral changes either to objective alterations in the environments in which these individuals interact, or to alterations in individuals' preferences, beliefs, or attitudes toward risks.

117 Id (explaining that under a risk-based regime, a legal system looking to decide which activities are dangerous "would encounter serious informational problems" and "making such determinations [would be] more difficult than evaluating behavior that has resulted in harm").


119 See Shavell, Foundations of Economic Analysis of Law at 577 (cited in note 82):

[Risk]-based sanctions do not require that sanctions be as high as harm-based sanctions, if the harm due to an act is probabilistic. . . . A party needs to have much higher assets to be deterred by the threat of sanctions for doing harm than by the threat of sanctions for committing an act, if the act causes harm only with a low probability.

For illustration, consider the example of an activity generating a $100 gain in 40 percent of cases and a $100 loss in 60 percent of cases. Under a risk-based system, the expected sanction is only $60; this in contrast to $100 under the harm-based possibility. If the actor possesses less than $100 but more than $60, effective deterrence can be achieved only under a risk-based system.

however, suggests otherwise. People faced with a series of decisions involving repeated choices with probabilistic costs or benefits often change their behavior despite no apparent alterations in their preferences or environments.

This gap between rational choice theories and reality, however, does not indicate that the hope of anticipating the behavior of individuals must be abandoned. In the special context of repeated choices, probability matching provides the theoretical background that is required to bring theorists’ models closer to the actual world. Because legal contexts are often typified by probabilistic costs and benefits, probability matching is of special interest for legal scholars.

This Article has demonstrated that there are at least three ways in which the legal system can address probability matching. First, to avoid inefficiencies resulting from probability matching, ex ante investment in law enforcement should be adjusted to take probability matching into account. Second, the legal system can implement a regime of ex post escalating sanctions and thereby differentiate between agents who repeatedly engage in a certain behavior and agents who engage in it only occasionally. These two methods manipulate incentives in order to adjust for probability matching. Third, the legal system may also avoid the conditions under which probability matching can occur. By using a risk-based rather than a harm-based liability scheme, the legal system minimizes the probabilistic nature of legal sanctions and induces individuals to behave as maximizers.

The discussion concerning the regulation of socially undesirable behavior finds a mirror image in another argument concerning socially desirable behavior. Probability matching indicates that individuals who face repeated choices regarding socially desirable activities may take risks that are too small. Consider, for example, an individual who can invest $100 in an activity that is expected to yield, with equal probability, either $0 or $300. Although the expected benefit from the activity is higher than its costs, a risk-neutral individual who faces the choice repeatedly is expected to invest too little in such projects. Although the individual would invest most of the time, she would occasionally forgo the opportunity, due to her inclination to “match” the probabilities. As with socially undesirable behavior, the legal system may apply different solutions. First, it may be desirable to increase the expected payoff of the project to induce the individual to invest. Providing subsidies to those who repeatedly engage in such projects may, under these circumstances, be efficient. Second, the probabilistic nature of the payoff may be minimized. This may be achieved by promising the individual a consistent reward for her efforts.

This last observation suggests that probability matching ought to have a larger impact on the legal system than investigated in this Arti-
cle. Further research is thus necessary to complement these findings. The legal regulation of repeated conduct (either wrongful or desirable) ought to reflect the realities of behavior as revealed by experimental literature. Our analysis has demonstrated that the legal system already applies various mechanisms to overcome the inefficiencies resulting from probability matching.