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DEALING WITH UNCERTAIN SITUATIONS

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Dealing with Uncertain Situations

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Abstract

There are two ways for a situation to be uncertain. Subjective uncertainty refers to not knowing facts. Objective uncertainty refers to future events that have not been determined yet. A wide ranging literature review finds that subjective uncertainty inhibits behavior, increases conserving resources and willpower, and stimulates search for information – though in crude, sometimes dysfunctional fashion. In contrast, objective uncertainty calls for action, reflected in agentic control, increased arousal, and greater willingness to take risks. Again, some responses are irrational, such as exerting more effort for less expected reward, and betting more on uncontrollable future than past events. With both kinds of uncertainty, attention is mobilized and emotion is prolonged. Our review uncovered multiple signs that some uncertainty is beneficial and heightens enjoyment as a kind of spice of life, or, in some cases, as a welcome hope that a bad outcome might still be avoided.

Keywords: uncertainty, effort, information-seeking, risk, conservation

Dealing with Situational Uncertainty

Uncertainty is a common problem in many spheres of life, including finances and investments, military conflict, government policy, health, romance, electoral politics, and sports. Sometimes momentous and consequential decisions must be made without adequate information. The United Nations Human Development Report 2021/2022 reported that for the first time in the report's history, global human development had declined for two consecutive years, indeed in 90% of countries worldwide — and it fingered rising uncertainty as a central problem and cause (United Nations Development Report, 2022).

The present manuscript undertakes to provide a preliminary model of the psychology of uncertain situations, based on conceptual analysis of what might be the most adaptive responses to different kinds of uncertainty and building from a close reading of diverse empirical findings. In particular, we recognize two forms of uncertain situations. People experience uncertainty insofar as the key facts, circumstances, or outcomes have not been determined yet. People also encounter situations that are already fully determined and established — but the people lack the knowledge of those facts, and know that they lack it.

These two kinds of uncertainty — uncertainty rooted in subjective ignorance vs. in objective reality — were recognized by Kahneman and Tversky (1982). They labeled the two types internal and external. (Our philosophical colleagues have suggested epistemic and ontological.) Previous research has shown that people express an awareness of these different types of uncertainty by using different language to describe them (Ülkümen et al., 2016). When the uncertainty is due to lack of knowledge, people talk about how “confident” or “sure” they are, but when the uncertainty is due to the event not being determined yet, people talk about how “likely” something is. We shall follow Guttel and Harel (2008) in labeling these two types of uncertainty subjective and objective uncertainty. We also treat them as orthogonal, so that a given situation may involve either, both, or neither.

The present review focuses on uncertain situations in which an objective outcome is possible. People can also experience uncertainty about themselves and their attitudes (Baumgardner, 1990; Hogg, 2009; van den Bos, 2009; Tormala & Rucker, 2007). Although some self-views have an objective reality (“I am a better-than-average swimmer”), many forms of self and attitude uncertainty do not have an easily-accessible objective outcome. The answer to whether a woman likes her new romantic partner, the latest trend in baked goods, or a particular movie does not exist outside her experience. The present model may not apply to uncertainty in which there is no objective reality, such as uncertainty about self or attitudes.

Theory

Situations are defined as uncertain to the extent that it is difficult to make a prediction about how they will unfold (FeldmanHall et al., 2019; Hirsh et al., 2012). The subjective experience of uncertainty is the awareness that one is unable to make a prediction because one does not know key facts. Objective uncertainty is the inability to make a prediction because the facts are not yet determined. Even with full knowledge of current circumstances, the person may find the situation uncertain because different outcomes are genuinely possible, such as during a closely contested game.

What would be the optimal or adaptive responses to the presence vs. absence of each kind of uncertainty? With subjective uncertainty (and objective certainty), the facts all exist but the person does not know them. In that case, taking vigorous action would be risky (because the person lacks information to make good decisions), whereas pausing to seek information would be useful. In contrast, if the uncertainty is also objective, and especially if the person knows all

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there is to know at present, then taking action may be the optimal thing to do, so as to steer events toward a favorable outcome as best one can.

Rather than treating subjective and objective uncertainty as two types, we shall treat them as orthogonal. Figure 1 describes the resulting 2x2 categories, in which uncertainty can be purely subjective or objective, or both, or neither. The “neither” cell is in a sense the control or baseline, given that the person is certain and the facts are definite -- so there is no uncertainty. To be sure, an interesting variation occurs when the person is mistaken, thus firmly believing something that is objectively and definitely false.

Another relevant mistake occurs when the person feels certain about something that in fact has not been decided yet: objective uncertainty but (mistaken) subjective certainty. (Obviously, mistakes only apply to the subjective. Objective reality cannot be a mistake, though disappointed perceivers may subjectively perceive it to be such.) The person firmly believes something to be true but it remains unsettled, such as assuming a couple is formally engaged when there has been no actual pledge.

To round out the theory section, we now discuss the main responses to uncertainty, including how they might differ as a function of whether the uncertainty is subjective or objective (or both). Following that, we will review the available evidence.

Preferences

Our assumption was that people dislike uncertainty, at least when they must make behavioral choices. Perhaps the most aversive would be the purely subjective uncertainty, in which the facts exist but oneself does not know them. This indicates that the problem of not knowing is specific to oneself. Objective uncertainty may be less frustrating or embarrassing than subjective, because the facts have not been determined. On that basis, people may be more comfortable taking action under objective uncertainty than certainty — even if one’s subjective uncertainty is exactly the same. Put another way, being uncertain about the relevant past or present facts depicts the self as deficient and may therefore be threatening in a way that being uncertain about the future is not. After all, no one can know the future, so the uncertainty is shared by all. Objective uncertainty may indeed have appeal (such as adventure) that purely subjective uncertainty lacks, the latter being simply a form of ignorance.

Meanwhile, many entertainments make liberal use of uncertainty. When the costs to self are minimal, such as when watching a suspenseful film, uncertainty can heighten emotion and hence presumably enjoyment. With movies and novels, the uncertainty is entirely subjective, given that the outcome has already been determined. It is possible, however, that people immerse themselves in these vicarious experiences to the extent that they cease to reflect on the fact that the outcome has already been decided, so that they empathically experience the characters’ situation — including its supposedly objective uncertainty.

Information Seeking

Subjective uncertainty means knowing that one does not know something. Insofar as that knowledge is important, a generally helpful response would be to seek information. Seeking information is particularly relevant when the objective facts are certain, and only one’s knowledge is lacking. If the situation is both subjectively and objectively uncertain (thus doubly uncertain), it may be helpful to get what information one can, but there is a limit as to what can be learned. Information seeking should therefore be maximal when subjective uncertainty combines with objective certainty. Information seeking begins with paying attention. Hence one hypothesis is that uncertainty will attract (more) attention and stimulate curiosity.

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How much information does one seek? The optimal response would presumably be to seek out mainly information that is helpful, relevant, and sufficient for one's behavioral choices. If the information is unpleasant, that may deter the person from seeking it. Irrelevant or pragmatically useless information should not be sought.

To be sure, an alternative theory might suggest that subjective uncertainty in general prompts a wide-open quest for information, including, at times, unhelpful and unpleasant information. Seeking unpleasant and impractical information might well occur if the impulse to seek information in response to uncertainty evolved long ago, in relatively simple animal minds. It is presumably easier to design a brain to turn up its general curiosity and alertness to information – than to design it to search for a very specific (and ad hoc) category of information based on analyzing the current situation. Simply seeking any and all information might befit a simple mental design and would likely get the job done in terms of enabling the animal to find out what it does need to know. Whether humans seek pragmatically useless, irrelevant, and/or unpleasant information will be a useful test case to tease apart these two theories. Information may be pragmatically useless when it pertains to fully determined situations about which nothing can be done. There would seemingly be no benefit from getting such information, at least not in the present. To be sure, if that ineluctable fact has consequences for one's own life, then one wants to know the fact and plan one's coping accordingly. But if the animal mind were designed to learn for unspecified future occasions, then it might automatically try to learn as much as possible even, at times, when the information is unpleasant and not practically useful.

Effortful Action and Risk-Taking

Often people have a choice between action and inaction, and inaction can involve a wait-and-see component. The difference between subjective and objective uncertainty may be decisive here. When the outcome is undecided (i.e., objective uncertainty), taking effortful action may be essential for steering events toward a favorable outcome. Similarly, taking some risks may increase the likelihood of a desirable outcome. In contrast, when the uncertainty is purely subjective, it behooves the agent to act cautiously and postpone action as long as possible, in the hope that information may be acquired so as to provide a valid basis for coping. Another hypothesis is that uncertainty is itself a cue to conserve resources (and so reduce effort). When the near future is uncertain and one cannot predict what will be needed, conserving more resources would be a useful way to ensure that unknown upcoming challenges can be met. Insofar as effortful action consumes energy, it may be adaptive to conserve energy in uncertain situations.

Emotion

One way in which the mind might focus attention on uncertain situations is by increasing emotional responses to uncertain situations as compared to certain situations. People may experience more arousal, feel emotions more intensely, feel emotions for a longer period of time, and become more sensitive to rewards. These emotional experiences may help orient an individual toward the uncertain situation.

Uncertainty may be generally aversive, and so it would give rise to anxiety, fear, frustration, and other negative emotions. Undoubtedly, having to make important decisions while lacking vital information would evoke negative emotions such as those. However, it is apparent that people often find controlled and safe doses of uncertainty to be appealing and even entertaining, such as in suspense novels and movies, watching sports, or gambling. An alternative hypothesis would be that uncertainty intensifies emotion of all sorts. One function of emotion is to direct and maintain attention, so emotional arousal might keep the mind focused

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adaptively on the uncertain situation. Focusing on uncertain situations would presumably be helpful among audiences seeking entertainment — as well as people coping with difficulties.

Our conceptualization of the effects of uncertainty on attention and emotion is related to the AREA (attend, react, explain, adapt) model, which suggests that people attend to new circumstances until they find an explanation for them (Wilson & Gilbert, 2008). Based on this model, situations that are poorly understood attract attention and invoke an increased emotional response until they are understood. After that, the normal adaptation processes may gradually reduce the emotional impact, but those processes begin sooner when certainty is achieved sooner.

Arousal is often regarded as preparation for action, so arousal might be heightened when action is called for — thus particularly in objectively uncertain situations. Uncertainty might therefore prolong emotional responses, so that high arousal is maintained while one deals with the uncertain situation.

Error Management

Presumably people are not frequently mistaken about whether they do vs. do not know an outcome (e.g., they know if they know they got a promotion). However, they can be mistaken about whether some objective circumstance has been determined or not. It would seem the more costly error is to assume something is certain when in fact it remains undetermined. For examples, falsely thinking that one has reached safety may cause people to drop their guard, and falsely thinking a deadline has passed might cause them to miss an opportunity. In learned helplessness, animals believe harm to be inescapable and fail to learn that it is escapable — a costly error (Seligman, 1972). In general, we assume it is more costly to err on the side of believing that nothing can be done (objective certainty) than the opposite, though one may waste energy and other resources pursuing a hopeless cause. Hence there may be a general bias toward assuming the future is objectively uncertain.

Evidence

Double Uncertainty: Both Subjective and Objective

We begin with the situation of maximum uncertainty: Objective outcomes have not yet been decided, and the persons also are aware the outcome of the situation cannot be predicted. These situations call for action, to steer events toward favorable outcomes — and decisions must be made despite that lack of information.

Increased Preference and Interest

People find situations that are objectively uncertain to be more interesting than situations that are objectively certain. Entertainment choices can provide insight into what attracts people's interest and attention. Participants offered the chance to watch a soccer match alone were more likely to choose to watch it if it was live (thus, the ending was objectively uncertain) than if it was recorded (subjectively but not objectively uncertain; Vosgerau, et al., 2006). Participants were also more likely to choose to watch a bachelorette-style reality tv show if they were told it was unscripted (rather than scripted) and were told that the woman had not chosen who she would pick yet (vs. she had already privately made her choice).

People also prefer and enjoy playing games they are uncertain about winning more than games they are certain of winning. Participants played two different video games and were randomly assigned to win one by a large margin and one by a small margin (counterbalanced; Abuhamdeh, et al., 2015). They were then told there was a little time left, and they could play another game of their choice. Most participants (69%) chose to play the game they had won by a small margin, even though they reported feeling less competent at that game. In a similar vein,

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adjustments to video games that assist weaker players increase enjoyment for both more- and less- skilled players (Vicencio-Moreira et al., 2015). Uncertainty about winning is associated with greater enjoyment and motivation, even though it comes at the cost of decreased likelihood of winning. People show a greater interest and engagement with situations that are objectively uncertain than situations that are objectively certain.

The idea of “potential” suggests that a person’s level of talent is uncertain but could be quite high. Having potential is energizing in a way that simple achievement is not. Despite the large amount of entertainment content available from confirmed-talented singers and comedians, people still choose to watch reality tv shows and open mic nights in which the performers are only potentially good. Tormala, Jia, and Norton (2012) showed that people prefer someone described as having great potential of achieving something more than someone described as having already achieved the same thing. For example, Facebook users were more likely to click on an advertisement saying that a comedian “could become the next big thing” than an advertisement saying the comedian “has become the next big thing.” Likewise, and again seemingly paradoxically, they were more impressed by a letter of recommendation saying that the candidate might win an award than that the candidate had actually won an award. In another study, the researchers found that participants engaged in more processing in the potential condition than the confirmed talent condition. When the value of something is more uncertain, it is more important to judge information well. Taking a chance on something of uncertain value may also give one an edge on others who wait for more certain information before attending or hiring.

Increased Effort

We noted in the theory section that subjective uncertainty recommends inaction (to wait for information and clarification) whereas objective uncertainty calls for action (to influence the course of events). When both uncertainties are present, their implications clash. We assume the pressure to do something will often take precedence, but the subjective uncertainty might make it more difficult to decide what to do.

Effort is often part of action, so a first prediction is that objective uncertainty will elicit increased effort. Research has found that uncertainty about a relationship causes people to put more effort into the relationship. Whether a romantic relationship will continue or end may be uncertain, especially in new relationships, and uncertainty may increase effort to help it recover and thrive. On days when dating couples report feeling more insecure about their relationship, they are more likely to make social media posts involving their partner (measured by Facebook posts over a two-week period; Emery et al., 2014). Insofar as making such posts requires effort and is felt as doing something (presumably positive) about the relationship, this finding suggests that uncertainty may motivate increased effort.

Another study manipulated whether participants felt anxious about a potential romantic partner (Eastwick & Finkel, 2008). Some participants were asked to think about a time when they were worried that this person might not want a relationship or might not care about the participant as much as the participant cared about the partner. These participants were more likely to report being willing to invest in the relationship (e.g. “I would be happy to rearrange my schedule to hang out with ___”) than participants in a control condition. Because the person they were asked to write about was a potential (not current) partner, the behavior was not motivated by fear of losing the partner. Rather, the effort was motivated by uncertainty over whether one could potentially attract the partner.

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Effort is particularly motivated when one is committed to the relationship and then feels uncertain. Sawicki and Agnew (2021) manipulated uncertainty by randomly assigning participants to list things from the previous day that had made them feel uncertain (vs. certain). Then they completed a scale measuring their willingness to sacrifice for their partner (e.g., “I am willing to do things for my partner even if he or she doesn’t always thank me”). Some participants were told to consider how their ratings reflected on their commitment before completing the scale. For them, the uncertainty induction strengthened the link between high commitment and high willingness to sacrifice (as compared to the certainty condition). In contrast, for those who did not reflect on the link between sacrifice and commitment, the opposite obtained: It was in the certainty condition that high commitment led to high willingness to sacrifice, not in the uncertain condition. Thus, when people are focused on how their actions reflect their commitment, uncertainty about the relationship may motivate highly committed people to make sacrifices to benefit the partner.

Undetermined uncertain rewards can increase effort more than certain rewards. Shen, Fishbach, and Hsee (2015) asked participants to drink about a quart and a half of water in two minutes, and they were told they would receive a cash reward if they succeeded. Participants in the certain condition were told they would receive \$2 if they completed the task. Participants in the uncertain condition were told that if they completed the task, the experimenter would flip a coin and they would receive either \$1 or \$2. It is important to note that in this study it was explicit that the potential reward had not been determined yet (objective uncertainty). 70% of participants in the uncertain condition completed the task while only 43% of participants in the certain condition did. Uncertainty consisted of the possibility of a lower reward and was explicitly said to be randomly determined, so the results were not due to the pursuit of a larger reward. It is ironic that the possibility of earning less money for the same achievement motivated people to exert more effort. The irrationality suggests again that responses to uncertainty are simple and crude rather than the result of sophisticated reasoning.

Uncertainty about an outcome can increase effortful adherence to health recommendations. Among women with abnormal pap smear results, women who indicated that the uncertainty associated with their result made them nervous were more likely than other, non-worried women to follow the doctor’s recommendation (such as getting a follow-up test or cryosurgery; Funke & Nicholson, 1993). In one meta-analysis, worry (an act that requires subjective uncertainty; Dugas et al., 2004) predicted greater likelihood of subsequent breast-cancer examinations (Hay et al., 2006). Admittedly, it is not entirely clear whether these situations are perceived as determined by the women involved. Although the presence of abnormal tissue is already determined, the long-term prognosis is likely not perceived as determined.

A more direct example would be medical situations in which one could prevent a not-yet-determined negative outcome. Among individuals unvaccinated for the flu, higher anticipated worry and regret, measured at Time 1, predicted taking the flu vaccine by Time 2 (one year later; Chapman & Coups, 2006). When the ultimate outcome of a situation could still be influenced, subjective uncertainty predicts more effort to obtain a more desirable outcome.

Increased Willingness to Take Risks

People take greater risks in situations that are objectively uncertain than objectively certain. Participants bet more before a die roll than after the die has been rolled (Rothbart & Snyder, 1970) and report being more willing to bet on the sex of a baby before than after it has been delivered (though in both cases they lacked knowledge of its sex; Brun & Teigen, 1990).

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Participants indicated that it was more exciting to make and less uncomfortable to lose a bet made before than after a soccer game, thus while the outcome remained objectively uncertain. Additionally, participants reported that the situation felt more uncertain before rather than after the outcome, though in both cases they did not know who would win. Apparently, it is uncomfortable not to know information that is objectively available, and undetermined outcomes feel more uncertain than determined outcomes that are unknown to the person. Double uncertainty feels more uncertain than purely subjective uncertainty.

The effect of preferring to predict before an outcome has been determined, rather than afterward, is increased when the stakes are high. Participants who were told they would receive electric shock if they were incorrect showed a significant preference for predicting before (rather than after) dice were rolled, despite subjective uncertainty being the same (Friedland, et al., 1992). In contrast, when wrong guesses did not bring shocks or indeed any consequences, participants had no preference for predicting before vs. after the dice were rolled. Thus, people are most sensitive to the difference between undecided and decided-but-unknown situations when the outcome will affect them.

Individuals with an internal locus of control have a stronger preference for predicting over postdicting than individuals with an external locus of control (Friedland et al., 1992). Feeling control over undetermined events, even completely random ones, may be a reason for taking greater risks in undetermined than determined situations. It also suggests people have a bias toward assuming circumstances are undecided and that they can potentially control or at least influence them.

Risk-taking in interpersonal contexts is also increased when less of the situation has been determined (Bodescu et al., 1995). In one study, individuals were told that they could request what they wanted from a pool of uncertain size (e.g. 250 points-750 points). If the total of all five participants' requests exceeded the total amount in the pool, no one received anything. Participants did not receive any information about others' requests. Participants who were randomly assigned to choose first requested more ($M=139$) than participants randomly assigned to choose last ($M=102$), and the relationship between position and amount requested was significant. With subjective uncertainty held constant, participants made more risky requests when others' choices were objectively uncertain.

Ignorant Uncertainty: Subjective Uncertainty and Objective Certainty

For many people, this situation of purely subjective uncertainty is the essence of uncertainty: There are facts, but one does not know them, and one knows that one doesn't know them. In such situations, the adaptive response would presumably be to seek information while holding off on action.

Information-Seeking

Impatience for Information about Determined Outcomes. Various animals (including humans) are willing to give up part of their reward to know about their reward earlier, sacrificing resources to get already-determined information (Bennett et al., 2016). In some studies, pigeons could peck a button that activated a possible reward, delivered 10 seconds later (McDevitt et al., 2016; Stagner & Zentall, 2010). Naturally they preferred the buttons with higher frequency of reward. But they showed a preference for a lower-probability reward button (20% instead of 50%) if that button offered an immediate signal as to whether a reward would be forthcoming. Whether the button they pressed would offer a reward had already been determined, and they wanted to know the result immediately. Essentially, they were disinclined to wait 10 seconds to get information about a determined outcome. Thus, they got smaller rewards but avoided the

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uncertainty during the 10-sec wait. Similar findings have been obtained with monkeys, who chose gambles with a lower potential reward (fewer microliters of water) over games with a higher potential reward if they would receive information about the outcome earlier (Blanchard et al., 2015). In fact, they sacrificed 20-33% of their reward to find out a mere 2.25 seconds faster. Humans are more rational, but the effect is still there: Rodriguez Cabrero, Zhu, and Ludvig (2019) found that people gave up around 8% of their rewards (on average) to get earlier information about their already-determined reward.

An important aspect of these procedures is that the information could not change the outcome. There was nothing the subjects could do to alter the outcome once the choice was made, yet even so they were willing to pay for immediate information rather than wait 10 seconds to find out — and even though the outcomes would have been better to wait amid uncertainty for that brief period. In other situations, early information may be pragmatically useful: For example, as soon as a hunter realizes that the prey will escape, it may be adaptive to abandon the hunt, either to conserve energy or to move on to stalk another prey (Vasconcelos, et al., 2015). Similarly, if employees learn earlier that they will be laid-off, they can more quickly apply for and start a new job. However, the desire for information in determined situations seems to apply broadly.

As subjective uncertainty increases, people's desire for information also increases. Van Lieshout et al. (2019) had participants guess and bet on the color of a marble and then offered them the opportunity to find out whether their guess had been correct — but at a cost (having to wait longer in the experiment). People were willing to wait longest when the marble guessing odds were even (50-50), as opposed to being more one-sided. The information had no pragmatic value. Participants were informed they would receive the outcome of all the bets at the end of the study, regardless of whether they learned the outcome of any given trial. Thus, the higher the subjective uncertainty, the more people were willing to sacrifice time to gain information about an already-determined outcome.

People seek information earlier when the outcome has already been determined than when it has not been determined. Nielsen (2020) entered participants for a prize drawing and manipulated whether the drawing had already occurred or not. Thus, objective uncertainty was manipulated. When participants were told the drawing had not yet happened (objectively uncertain), they preferred later resolution of the uncertainty than when participants were told the drawing had already happened (objectively certain). Delaying the drawing (rather than merely delaying the announcement of already-determined results) may allow participants to continue to feel some illusion of control or exercise magical thinking over the future results. Information-seeking is more appealing when the outcome has been determined than when it has not.

Increased Attention. Subjective uncertainty attracts attention, consistent with the general information-seeking response. An eye-tracking study measured how long participants stared at a stimulus that was paired with an aversive sound on 0%, 50%, or 100% of trials (Hogarth et al., 2008), though the pairings were not made clear to the participants in advance (but they could learn). They gazed longer in the uncertain (50%) condition than in either of the others. Moreover, the effect disappeared among participants who failed to learn the relative probabilities. Thus, the person had to recognize the uncertainty for attention to be preferentially directed toward it. The effect was described as “looking-for-learning” by Hogarth, Dickinson, and Duka (2010). People shift attention toward uncertainty to improve their ability to predict the environment.

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Research on distraction provides further evidence that uncertainty attracts attention. Isikman et al. (2016) assigned participants to read a passage while seated near a gift for them. Uncertainty was manipulated by having the gift in either a transparent or a wrapped box. In the uncertain (wrapped) condition, participants enjoyed the reading passage less than in the clear condition. The effect was mediated by the extent to which participants were ruminating about what was in the box. An alternative explanation might be that uncertainty simply increased unpleasantness overall, but this possibility was contradicted by a further study in which people were focused on a negative experience (watching a poor-quality video). In this study, uncertainty led to higher enjoyment ratings. The implication is that peripheral uncertainty can reduce both positive and negative impact of the primary stimulus — presumably because it siphons attention away from the primary stimulus. For present purposes, the important thing is that attention favors the nexus of uncertainty.

Unpleasant and inaccurate information. When outcomes are determined, people will sometimes seek even unpleasant information to reduce subjective uncertainty. People are willing to pay to eliminate uncertainty about what would have happened if they had acted differently. After making a gamble, the majority of participants were willing to pay to find out where the winning card had been in the array, even though this information did not change the outcome (Barkan, Danziger, & Shani, 2016). Again, the outcome had already been determined, and they could do nothing about it, but they still wanted the information.

In a similar vein, some participants who played a risk game chose to find out how much more they could have won (FitzGibbon et al., 2021). The task involved inflating a simulated balloon, such that each new inflating puff increased the potential reward — but at some point the balloon would burst, whereupon all rewards were forfeit. After the task was complete (the outcome for that participant was no longer uncertain), participants could choose to find out how much they might have earned by continuing to inflate. Participants who chose to find out how much more they could have earned were sadder than others, and it failed to improve performance on future trials. In fact, the increased sadness was associated with riskier bets and poorer outcomes on subsequent trials. Thus, the impulse to reduce uncertainty by gaining information was emotionally costly and even associated with poorer further performance. Participants may have scored more points on the task and been happier if they had been willing to remain uncertain.

When subjectively uncertain, people seek out additional information and clarity in already-determined situations. Interviews with private detectives found that most clients chose to see available pictures of their spouse committing adultery, rather than just reading the report (Kruger & Evans, 2009). Participants chose to enlarge thumbnails of negative social images (e.g., people standing around a dead body) more often than neutral social images (Oosterwijk, 2017). By enlarging the image, participants may have been able to reduce their uncertainty about the content of the images, but at the cost of seeing unpleasant images better. Participants chose to see transcripts of strangers in the lab criticizing their preferences, even when they reported that seeing the transcripts would cause more harm than good (Kruger & Evans, 2009). By reporting that it would cause harm, participants may have been bracing themselves for seeing the negative information, but presumably one would just be better off not seeing a stranger's criticism of one's preferences. Importantly, these pictures, transcripts, and images already existed, so there was no objective uncertainty.

Participants will even accept electric shocks to reduce their subjective uncertainty in a determined situation. Hsee and Ruan (2016) seated participants in front of a variety of joke pens

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that could shock them (ostensibly while they waited for the experimenter). Some pens were labeled as pens that would shock when clicked, other pens were labeled as pens that would not shock when clicked, and others were labeled as unknown. Participants chose to click the subjectively uncertain pens (that might or might not shock them) significantly more often than the two types of clearly labeled pens. A follow-up study used buttons, some of which caused an aversive noise. Participants pushed more buttons when a smaller proportion of the buttons were labeled (thereby increasing their own exposure to noise stress), and the more buttons they pushed, the worse they reported feeling. People chose negative information over experienced uncertainty and were worse off as a result.

Discomfort in response to uncertainty about determined situations is one reason people seek information (Shani et al., 2008). In a hypothetical lottery example, participants were asked to imagine they forgot to send in a lottery form. They were asked to imagine that they saw the winning numbers and, although they could not remember every number they had chosen, they remembered that either two (low probability of having the winning numbers) or five out of the six (high probability of having the winning numbers) were numbers they had chosen. Participants with a greater chance of having won reported being more likely to check whether they would have won (if they had sent in the form) than participants with a lower chance, and this effect was mediated by discomfort. Participants reported choosing the unpleasant knowledge that they would have won a lottery over the discomfort of uncertainty. Although this particular study measuring discomfort was hypothetical, other studies in the same paper found that participants were more likely to wait for the results of a lottery that would not pay out (participants are explicitly told all the money is gone) if they were led to believe they had a high chance of having a winning number than if they were led to believe they had a low chance of having a winning number.

Most participants said they would advise others not to pay for unpleasant information or information that does not change their outcomes (Barkan et al., 2016). Although most “choosers” were willing to pay to find out where an unchosen winning card had been in an array, most “advisors” (who did not get to make a choice) recommend not paying to find out. Participants reported wanting to find out whether a former romantic partner had been sexually unfaithful to them ($M = 5.76$ on a 0-10 scale), but would discourage a friend from finding out ($M=3.40$). Participants reported basing their own decision to seek information more on their curiosity than the usefulness of the information. They also reported basing their decision for advising others on the usefulness of the information more than curiosity. Thus, people advise others to avoid painful and practically useless information, but for themselves they want the information to resolve uncertainty.

Sometimes, to be sure, people choose to remain uncertain rather than get the information — particularly if the information could include unpleasant facts accompanied by requirements for action. Howell and Shepperd (2013a, b) cited evidence that many people tested for HIV fail to come get their test results, presumably in some cases because they do not wish to deal with knowing they tested positive. Their studies showed that people avoided getting medical feedback if it contained the possible obligation for long-lasting, unpleasant treatment. In a follow-up (Howell & Shepperd, 2013b), requiring people to contemplate the implications of feedback made them less prone to avoid potentially bad medical feedback — but only if the disease would be (easily) treatable. Around half continued to avoid the feedback if it meant finding out one had a dangerous and untreatable disease. Nevertheless, the conscious contemplation enabled people to recognize the advantage in finding out whether one would benefit from a simple treatment.

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Two forms of curiosity were analyzed in relation to uncertainty by Zedelius, Gross, & Schooler (2022). One had generally positive effects and was associated with a joyful search for knowledge and openness to experience (Litman & Silvia, 2006). In contrast, the one motivated by uncertainty reduction, called deprivation curiosity, was found to be associated with various errors and irrationality (“inquisitive but not discerning” in the authors’ titular phrase). Such individuals falsely claimed to recognize objectively unfamiliar information and made-up concepts. They imputed more meaning to nonsensical “bullshit” statements and were more willing than others to believe false information. These findings fit the view that the desire to reduce uncertainty opens the mind to all manner of information, thereby facilitating the acquisition of valid knowledge but also enabling the mind to accept falsehoods and mistakes.

Preference for Certainty

Situations in which the actor lacks knowledge (subjective uncertainty) but the outcome is determined (objective certainty) are undesirable. Rats in environments where they will be shocked prefer versions of the environment with more information (e.g. signals indicating what is coming, temporal regularity, consistent duration of shocks) over versions of the environment with less information (for a review, see Imada & Nageishi, 1982).

People report preferring to avoid uncertainty about determined outcomes. Across several studies, some participants were randomly assigned to experience uncertainty or assigned to a full knowledge condition, while other participants were asked to choose whether they would prefer the certain or the uncertain condition (Wilson et al., 2005; Kurtz et al., 2007; Ruan, et al., 2018). In these cases, there is objective certainty. In one study, participants watched a shortened version of the movie “Rudy” and then were given a few different possible endings for what happened to Rudy after the movie (Wilson et al., 2005). Participants who were told which ending was true (randomly assigned) reported a greater decrease in positive mood over time than participants who were left uncertain about which ending was true. However, participants do not intuit these benefits, and in a separate group of participants, ninety-one percent said they would choose the certain condition. People preferred certainty, yet people assigned to have certainty were actually less happy than those who continued to be uncertain. A further implication of these findings is that findings based on imagined or hypothetical responses should be interpreted with considerable caution, given the mismatch between imagined responses and actual outcomes. Still, findings based on hypothetical scenarios do reveal what people believe they prefer.

Decreased Effort

Uncertainty may lead to a tendency to conserve energy while waiting for more information. Some evidence in support of this conjecture was provided by Anselme and Gunturkun (2019). Uncertainty in the food supply prompts many animals to conserve food, not only by storing food but even by putting on weight and fattening up. When food is scarcest, such as in deep winter, some animals conserve energy by hibernating, thereby severely curtailing all effortful activities. These patterns suggest that the pattern of responding to uncertainty by conserving resources may have evolved rather early and would therefore be a simple response pattern rather than a rationally guided or tailored one. Conserving effort would be one form of a possibly broad pattern of conserving resources under uncertainty. When the outcome has been determined, effort cannot change the outcome. Studies have found that subjective uncertainty regarding an objectively certain outcome causes a decline in effortful performance on an unrelated task (Alquist et al., 2020; Core et al., 2018). In one study, participants were initially told that the study involved responses to speeches, so some participants would give a speech while others would listen. Having to speak in front of others is often a source of anxiety, so being

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assigned to give a speech was essentially bad news. Participants were randomly assigned to be told they would either give a speech or listen to a speech — or in a third, uncertain, condition, they were told the experimenter did not have the condition assignment sheet with her and she would have to check and tell them later. In this case, it was clear that their condition had been determined, but the participant did not know what it was. At this point all participants were given the performance measure, which was the electronic board game *Operation*, requiring careful self-control to extract organs from a depicted patient while avoiding contact with the rest of the patient's body as depicted on the board. This task has been used in multiple studies as a measure of self-control and requires both effort and skill (e.g., DeWall et al., 2008; Englert and Bertrams, 2013). Participants in the uncertain condition made the most errors, indicative of poorest performance. The uncertain condition (mere possibility of having to give a speech) produced significantly worse performance than certainty of bad outcome (definitely will have to make a speech).

It is possible that the effect in the above study was due to participants in the uncertain condition being more distracted than participants in the certain conditions, but additional studies have found poor performance on tasks even after uncertainty has been resolved (Alquist et al., 2020; Milkman, 2012). Participants in one study were recruited in exchange for an instant-game lottery ticket with predetermined but concealed result (Milkman, 2012). In the certainty condition, they were permitted to scratch off the ticket immediately to find whether they had won. In the uncertainty condition, they were required to wait a full 20 minutes to get their ticket and learn their fate. After scratching off the ticket, all were then asked to do arithmetic problems until they finished, wanted to quit, or gave up. Such task persistence has been a frequent measure of self-regulatory effort (e.g., Vohs et al., 2008). Participants in the uncertain condition put in less time and effort on the arithmetic task than those in the certain condition. Participants in the certain condition persisted longer even though almost all of them found out they had not won anything in the lottery. Thus, again, subjective uncertainty combined with objective certainty led to a reduction in effort.

The studies of effort reported thus far in this section were conducted as part of a research program on ego depletion, defined as a state of reduced executive function and self-control after having exerted energy (Baumeister et al., 1998; Baumeister & Vohs, 2016). The original hypothesis had been that coping with uncertainty produces ego depletion. After some years of research, the authors revised the theory to propose that encountering (subjective) uncertainty simulates ego depletion. Ego depletion is essentially a response of conserving energy (Muraven et al., 2006), and uncertainty may be a broad cue to conserve resources, including one's energy. This would presumably be adaptive for coping with the upcoming unknown circumstances.

Converging evidence that subjective uncertainty with objective certainty produces inaction was provided by Tversky and Shafir (1992). Their participants imagined being offered an attractive gamble: a coin flip with an even chance of winning \$200 or losing \$100. Some were told to imagine they had won, and others were told to imagine they had lost. Then they were asked would they take the gamble a second time. The majority in both conditions said yes. Then, in a third condition (and later), they were asked whether they would accept the second gamble before they found out whether they had won the first. The objective certainty was explicit: They were told the coin had been flipped but they did not yet know the outcome. This time, nearly two thirds refused the second gamble, even though most participants had already said they would accept the second gamble regardless of the outcome on the first. Subjective uncertainty about a determined outcome resulted in decreased effort and inaction. The irrationality of the response is

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consistent with a deeply rooted impulse to inhibit action and conserve energy when facing uncertainty.

Hope

Hope is only possible in situations in which an individual is subjectively uncertain and believes the situation to be objectively uncertain as well. Hope is based on positive uncertainty, focusing on the possibility of a highly desired outcome. In a famous scene from the movie *Dumb and Dumber*, Mary tells Lloyd that there is a “one out of a million” chance they would end up together, and Lloyd replies, “so you’re telling me there’s a chance!” Although the whole premise is that Lloyd is not very bright, this line stands out and has resonated widely because people can relate to the idea of focusing on the objective uncertainty of a situation despite very slim odds.

Physicians may also prefer allowing individuals to believe a situation is objectively uncertain over reducing uncertainty with negative information. In Davis’s (1960) study of children with polio, the researchers found that parents’ knowledge of the likely trajectory of their children’s condition did not increase over time, even as the doctors became more certain of the child’s trajectory. Davis observed that “uncertainty can be grounds for hope as well as despair.” Although changes in medical ethics have made keeping information from patients less common, an article in a nursing journal encouraged practitioners to consider whether patients view an uncertainty as positive before attempting to provide information to resolve it (Neville, 2003).

Subjective Uncertainty

We have covered two of the four cells in our taxonomy. Before moving on, it is necessary to consider some cases that bridge those two. These studies typically have focused on subjective uncertainty without it being clear whether the objective facts were certain or uncertain. These studies have elucidated how subjective uncertainty (knowing that one does not know something important) alters emotional responses.

There are several reasons uncertainty may intensify emotional reactions. First, emotion may help draw attention to the uncertain issue, even interrupting other ongoing activities for that purpose. Second, emotion facilitates learning (Bradley et al., 1992). Both are useful for helping the agentic executive function deal with uncertainty regardless of whether the situation is objectively uncertain or determined. Third, increased arousal may help mobilize the individual to take action, in case the situation remains objectively uncertain and the person can influence events. Multiple lines of work indicate that uncertainty magnifies emotion.

Higher Arousal

Arousal is a basic part of many emotions (Russell, Weiss, & Mendelsohn, 1989; Schachter & Singer, 1961), and it facilitates behavioral responses, such as by increasing adrenaline (Bogdonoff et al., 1960). Complete absence of arousal is a state of passive unconsciousness (a coma; Laureys, et al., 2009).

Arousal increases in response to uncertainty. Participants in a study by de Berker et al. (2016) completed 320 trials in which they saw various rock pictures, one of which was followed by an electric shock to the participant. One rock was more likely than the other to cause the shock, and the same rock had the higher probability (though not guaranteed) for a series of 26 to 38 trials, whereupon the other became more likely. Hence it was possible for participants to learn the probabilities and adjust their predictions accordingly. Arousal was measured by pupil dilation and galvanic skin response. Arousal was highest when the probability was most uncertain (i.e., close to 50%). Moreover, participants whose arousal most closely tracked the probabilities (i.e., greater pupil diameter when the odds approached 50-50) performed best across the task. Thus, increased arousal accompanying uncertainty was associated with better learning.

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Subjective uncertainty can be inferred from wrong answers on a judgment task, because wrong answers indicate guessing rather than knowing what is right. Urai, Braun, and Donner (2017) instructed participants to judge whether the percentage of dots moving in a given direction was higher or lower than in a comparison reference video. Arousal, measured by pupil dilation, was higher before wrong than correct answers, thus again indicating a link between uncertainty and arousal (assuming that wrong answers often reflect guessing). Furthermore, participants with greater pupil dilation on a given trial were more likely to switch their answer on the next trial, a behavioral marker of uncertainty about one's previous response. Each trial was independent, so letting uncertainty about a previous trial influence response on the current trial only added error. Nevertheless, the finding suggests a link between uncertainty, arousal, and the impulse to try something else.

Lanzetta and Driscoll (1966) exposed participants to a series of trials in which the outcome was either shock or no shock, reward or no reward, or reward or shock. Participants could press a button to learn in advance what was coming. They chose to get this information on average about 2/3 of the trials. On trials in which participants would get either a shock or reward, they had a lower galvanic skin response to either outcome when they chose to get information in advance. Thus, the outcome increased arousal if preceded by uncertainty. Put another way, good and bad surprises are both exciting.

In another study on anticipating electric shocks, participants knew an electric shock would occur but were left uncertain as to exactly when it would come (Averill & Rosenn, 1972). They wore headphones and could choose whether to listen to music or, on another channel, to listen for a warning tone that would precede the shock. The choice was between avoidant and vigilant coping. As shock intensity increased, people shifted to favor the warning tone. This shift was significant even when the shock was inevitable, though it was understandably greater in a condition that enabled them to press a button to prevent the shock. Nevertheless, a sizable number of participants in both conditions preferred to listen to music rather than listen for the warning tone. Physiological arousal and stress were greater among those who chose to listen to music than those who waited for the warning tone. Thus, the uncertainty about when the shock would occur was higher among those not listening for the warning, and it produced higher arousal.

Even uncertainty about uncertainty – not knowing the odds – produces arousal, as shown by FeldmanHall et al. (2016). They also found that higher arousal led to making more rational decisions when the odds were clear — but led to gambling more when the odds were ambiguous. This finding fits the earlier point about objective uncertainty leading to higher risk-taking (and here mediated by arousal).

A recent study measured arousal following two orthogonal manipulations of uncertainty (Brown et al., 2021). Arousal (skin conductance) increased more among participants who had been randomly assigned to write about things that made them feel uncertain about themselves, as compared to certain about themselves. Next, participants were given a description of their university as either united (with strong leadership, a unified student body, and common goals) or not (loose leadership and diverse students and goals). The message about unity reduced arousal compared to the other, mainly among those who had written about personal uncertainty. One implication is that aligning with a strong group reduces feelings of insecurity (and the arousal that accompanies it), consistent with social identity theory (Tajfel, 1978; Hogg, 2000) and historical and cross-cultural evidence reviewed by Henrich and Muthukrishna (2021).

Greater Sensitivity to and Drive for Rewards

As discussed above, uncertainty seems to increase responses to punishment (e.g., shocks), which facilitates learning. Uncertainty also increases responses to rewarding stimuli. Unpredictable outcomes are inherently more uncertain than predictable ones. Even rat brains show greater response to unpredictable than predictable rewards. Rats showed a greater dopamine (reward) response to cocaine when it was administered unpredictably (i.e., following a stimulus signal only 50% of the time) than predictably (100%; D'Souza & Duvauchelle, 2008). Again, a stimulus elicits a more intense response when it is unpredictable than predictable.

Berns et al. (2001) administered human participants small doses of juice or water. In the predictable condition, the dose came every 10 seconds and alternated regularly between juice and water. In the unpredictable condition, participants were given a squirt of water or juice at a variety of intervals that averaged 10 seconds and whether they got water or juice was random. Uncertainty increased activation of reward-relevant areas of the brain in response to rewarding stimulus: fMRI brain scans revealed greater activity in the medial orbitofrontal cortex and the nucleus accumbens (associated with reward sensitivity) in the unpredictable than in the predictable condition.

Surprise rests on unpredictability and hence also invokes uncertainty. Surprise likewise intensifies responses to rewards, as indicated by brain (dopamine) activity. Fiorillo and colleagues (2003) trained monkeys to recognize visual cues associated with different probabilities of receiving a liquid reward. Dopamine neurons responded more strongly to the cues associated with *lower* probabilities of reward. When reward was guaranteed, the cue elicited very little dopamine response. The authors interpreted their findings as indicating that information is most valuable and hence most rewarding in uncertain situations.

People who had to wait for information (e.g., what gift card they would receive) had a more positive reaction (e.g., rated the store of the gift card more favorably) than people who received the same information immediately (Ruan et al., 2018). Uncertain participants only felt more positively than certain participants after the uncertainty was resolved, implying that the resolution (not just the uncertainty alone) caused the positive affect. People seem unaware of or indifferent to these affective benefits of uncertainty, however. When participants were allowed to choose their experience, the majority chose to avoid uncertainty in these situations.

In addition to increasing the extent to which something is rewarding, uncertainty may also increase the drive for rewards. fMRI research on humans has found that uncertainty increases activity in the insula, an area associated with drive states (Wiggin, Reiman, & Jainn, 2019). Participants who were asked to think and write about things that made them curious reported a greater desire for reward than participants who were asked to think and write about a situation in which their curiosity had been resolved. As discussed earlier, uncertainty is a closely-related prerequisite to curiosity. Participants in the curious (uncertain) condition reported being willing to spend more money on a hypothetical vacation than participants in the resolved curiosity (certain) condition, and the relationship between curiosity and amount spent was mediated by self-reported desire for rewards. Although it was not measured directly, Wiggin and colleagues posited that the arousal accompanying curiosity may lead to a broad desire for rewards.

Greater Emotional Intensity and Influence

Uncertainty can intensify emotion. Participants in a study by Bar-Anan and colleagues (2009) watched positive or negative movie clips while reciting phrases that manipulated uncertainty. Uncertainty was induced by phrases such as "I'm not sure what's happening,"

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certainty by phrases such as “I see what’s happening,” and a neutral control condition had irrelevant phrases (e.g., “my phone rings”). Self-rated emotional intensity was greatest in the uncertainty condition: The positive emotions were stronger in response to the positive film clips, and the negative ones were stronger in response to the negative clips.

Outside the laboratory, there is also evidence of intensified emotion. Among adolescents with cancer, those who reported more uncertainty reported significantly more distress ($r=.55$; Neville, 1998). Similar findings emerged from a study of patients with chronic hepatitis who were engaged in watchful waiting (Bailey et al., 2009). In that sample, patients who reported higher levels of ambiguity surrounding their illness also reported more intense depressive symptoms, lower quality of life, and more intense pain, as compared to those who reported less ambiguity. Importantly, these studies did not control for prognosis, so it is possible that these effects are driven by individuals with worse prognoses feeling more uncertain and also experiencing more pain and depressive symptoms.

In work using fMRI and EEG measures, Seidel et al. (2015) found brain activity suggestive of greater emotion in response to uncertainty rather than certainty. Participants anticipated a shock with either 50% or 100% probability. The 50% condition produced more activity in brain regions related to affect (lateral OFC, anterior insula, and dorsomedial PFC) than the 100% condition.

Several lines of work have confirmed that uncertainty intensifies reactions to interpersonal events. Van den Bos (2001) subjected participants to a division of rewards between themselves and another person who had performed about equally well on a task. Some were permitted to suggest what they thought they deserved, while others were denied the chance to express an opinion. The latter were more upset — but only if they had also been manipulated into uncertainty by writing down their personal feelings about uncertainty (as opposed to personal feelings about watching television). Likewise, in a study of victims of ostracism, those who were uncertain about the reasons for their silent treatment felt more threatened than those who were clear about the reason (Sommer et al., 2001).

Uncertainty also has been shown to increase the effect of affect on decisions and to increase the likelihood of choosing an affectively superior option (Faraji-Rad & Pham, 2016). Faraji-Rad and Pham manipulated uncertainty by asking participants to generate synonyms either for certainty or uncertainty. Participants primed with uncertainty were more affected by a mood manipulation when rating a set of headphones than participants primed with certainty. In contrast, participants primed with uncertainty were less influenced by the supposed expertise of a critic than participants primed with certainty. Thus, uncertainty increases the impact of mood (but not other peripheral cues) on decisions, even when the mood is irrelevant to both the uncertainty and the choice. The authors propose that this effect is due to uncertainty increasing the focus on the self, which increases the focus on emotions.

Prolonged Emotion

Subjective uncertainty also increases the duration of emotions, both in situations where the outcome is objectively determined and undetermined. Multiple studies have shown that when participants were left uncertain about a positive outcome, they remained happier for longer time than participants who were not left uncertain. (e.g., Kurtz et al., 2007; Wilson et al., 2005). For example, participants were assigned to exchange information with ostensible opposite sex partners (Wilson et al., 2005). They were asked to pick the person they thought would make the best friend for them and write a paragraph about why that person was their favorite. Participants were told that all three interaction partners had chosen them as their favorite and read the

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paragraphs describing why. Participants in the certain condition were told which partner wrote which paragraph while participants in the uncertain condition were left uncertain about which partner wrote which paragraph. Participants in the uncertain condition were significantly happier after a delay than participants in the certain condition.

People can be happier about winning one prize than two, if the one is boosted by uncertainty (Kurtz et al., 2007). Participants performed a long initial task and were told they could spin a roulette wheel that offered a 1 in 5 chance of winning a prize. They had already rated a series of possible prizes and selected their two favorites. For everyone, the roulette wheel indicated a success. At this point, procedures diverged. Those in the certain condition spun a second time to see whether they received their first or second choice. In the uncertain condition, they were told they would spin the second wheel later, at the end of the session. And in a third (two-gift) condition, they were told that they could have both of their favorites. Participants were all happy after learning they had won a prize. Happiness declined rather rapidly in the certain and two-gift conditions but stayed high longer in the uncertain condition.

Uncertainty before a positive outcome also keeps the less-desirable alternative salient. The awareness that things could have easily been worse can contribute to positive affect (Roese, 1994). Yang, Gu, and Galak (2017) told participants that one per five hundred peanut M&M candies was rancid, and then the participants ate some peanut M&Ms. Participants who were assured that the M&Ms they ate had been checked and none were rancid reported being happier for less time after consuming the M&Ms than participants who were offered no such reassurances.

A second study by Yang and colleagues (2017) emphasized the importance of keeping the uncertainty salient. Some participants were assigned to view photographs of mountain scenes, while other participants were left uncertain about whether they would see photographs of mountain scenes or grisly pictures of eye surgery. After getting this initial information, all participants were distracted by a 5-minute filler video. After that, half of each group were reminded of what they would (or might, in the uncertain condition) see, and the other half were not thus reminded. All participants saw the mountain scenes. Among those who had been reminded, the uncertain ones reported being happy longer than those in the certain condition. The difference was not found among those who were not reminded of how things could be worse.

Unwarranted Certainty: Subjective Certainty with Objective Uncertainty

We turn now to the cases in which the person is subjectively certain but crucial external facts remain undecided. Even in the absence of subjective uncertainty, the objective reality of the situation can be uncertain. Golman and Loewenstein (2013) wrote about “not knowing and not knowing what one doesn’t know” (or Donald Rumsfeld’s “Unknown unknowns”). Outside of one’s knowledge, one’s relationship could be in peril, one’s job could be on the rocks, or one’s investments may be less secure than anticipated. Not recognizing these situations can lead to missed opportunities to nudge outcomes in a desired direction. Additionally, one may miss opportunities to seek out important information. Although uncertainty is often treated as a purely negative experience and is indeed often accompanied by unpleasant feelings, the experience of uncertainty, like the experience of pain, is a useful signal about one’s environment.

Underappreciation/Underrecognition of Objective Uncertainty

Although many animals respond differently to situations that are uncertain vs. certain (e.g., variable vs. fixed reinforcement schedules; Ferster & Skinner, 1957), not all animals seem to be aware when a situation is uncertain. In one study, dogs were either shown in which box a treat was placed or were not shown where the treat was placed (Bräuer et al., 2004). The boxes

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had small holes in them that the dogs could look or smell through to determine the location of the treat. The dogs were trained to press one of two levers to choose a box. Dogs who did not see where the treat was placed were no more likely to try to smell or look for the treat before pressing the lever than dogs who were shown where the treat was placed. Dogs didn't seek out additional information when information was missing.

In contrast, humans and some other animals, such as dolphins and rhesus monkeys, are more likely to skip trials or leave the task when the correct response becomes less clear (Smith et al., 1995; Beran et al., 2015). Smith et al. (1995) asked humans and a dolphin to indicate whether a pitch was high (2100 Hz exactly) or low (1200-2099 Hz). If participants gave the right answer, they were rewarded. If participants gave the wrong answer, they had to wait for the next trial. Participants were given an "escape" option that skipped the current trial, and if the escape option was used indiscriminately, it was taken away for a period of time. Both humans and the dolphin subject were more likely to escape trials in which the pitch was close to the boundary between the two categories (thus making the correct answer more uncertain) than when the pitch was clearly low. Some animals are aware (at some level) when they do not have the necessary information to get the answer correct.

The ability for children to prepare for multiple possible outcomes seems to develop in the preschool years, around the same time as other future-oriented behavior. Redshaw and Suddendorf (2016) dropped a treat into a tube with two openings at the bottom. Three and four-year-old children (though not two-year-olds) quickly learned to put a hand under each tube, to be sure to catch it. In contrast, adult great apes merely guessed with one hand and never learned to anticipate both possible outcomes. Thus, awareness of multiple alternatives (thus objective uncertainty) comes more readily to humans than to other apes.

Even robot quadcopters and remote-controlled cars have fewer damaging crashes when uncertainty of the likelihood of collision while navigating a particular environment is included in the algorithm determining their movements (Kahn et al., 2017). In these cases, the vehicles drive more slowly in more uncertain situations than certain situations, allowing the vehicles to incur less damage when they do make an error than vehicles without uncertainty included in the algorithm.

As additional evidence of the value of being aware when a situation is objectively uncertain, participants chose advisors who gave a percentage likelihood or said one team was "more likely" to win over advisors who simply stated which team they thought would win (Gaertig & Simmons, 2018). However, participants still preferred an advisor who was confident about their probabilistic advice than an advisor who prefaced with, "I am not sure but..." People want advisors who are appropriately aware of uncertainty, but confident.

Although humans can be aware of uncertainty, people are sometimes less uncertain than the situation warrants. Across multiple studies by Dunning et al. (1990), participants answered various questions about another person, such as another participant they had just interviewed. Questions including predicting how the other person would react, such as which magazine to choose, or whether to return a recently found \$5 bill. They were also asked to rate their confidence in their answers. Participants were generally overconfident as indicated by lesser accuracy than they had predicted, even when being inaccurate about their confidence decreased their likelihood of rewards.

People were similarly overconfident when predicting even their own behavior in the future (Vallone et al., 1990). Participants were asked to estimate their likelihood of having a variety of experiences in the next quarter or year (e.g. study later than 3am; visit San Francisco).

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Although participants expressed an average confidence across items of 82.3% (on a scale of 0-100% confident), participants' average accuracy was only 68.2%. Participants were particularly inaccurate when they predicted something that went contrary to their perceptions of the base rate (predicting something for themselves that they reported as unlikely for most people or predicting something would not happen to them that they indicated was likely for most people). Uncertainty about their future was warranted (participants were wrong about 30% of the time), but participants were overconfident about their knowledge about their future.

Consequences of Unwarranted Subjective Certainty

If individuals are certain that an unpleasant thing won't happen to them, they may not engage in the behaviors necessary to prevent it. Research on risk perception supports the idea that being aware that one might be at risk of car accidents, colon cancer, and covid-19 transmission predicts seatbelt use, cancer screenings, and hand-washing, respectively (Atkinson et al., 2015; Sheveland et al., 2020; Wise et al., 2020). Put another way, people who were more certain that these things would not happen to them were less likely to perform those helpful behaviors. Being aware of objective uncertainties thus enables people to take precautions.

Making people aware of their ignorance (reducing subjective certainty) also decreases extreme views (Fernbach et al., 2013). Participants were asked to rate their position and perceived knowledge on a particular policy and were asked to describe the causal chain of events that would come from implementing the policy. Then, they were asked to rate their position and perceived knowledge again, as well as their certainty about their position. Participants gave less extreme ratings of their position after writing about the policy than before. Additionally, uncertainty mediated the relationship between decreases in perceived knowledge and decreases in extremity. This finding suggests that political extremism is often supported by an exaggerated sense of subjective certainty.

There are even negative *affective* consequences to being overconfident (less uncertain than is warranted). Participants who were overconfident about their likelihood of making shots in a basketball shooting drill were less satisfied with their performance than participants who were underconfident or accurate (McGraw et al., 2004). In a separate study, participants who were told that many people are overconfident about their shooting accuracy were more satisfied with their performance than participants who were not warned about overconfidence. By decreasing participants' certainty about their upcoming performance, researchers increased their satisfaction afterward.

Learned helplessness is another example of the costs of viewing an undetermined situation as certain. In classic studies, dogs who were unable to escape an electric shock later made no attempt to escape the shock even when escape was possible (Seligman, 1972). The dogs reacted as though the outcome (how long they would be shocked) was determined, even when it was not. Similar to our conceptualization of uncertainty, Maier and Seligman (2016) distinguish between situations in which the actor is objectively helpless (unable to avoid a particular outcome) and situations in which the actors perceive themselves as helpless when the outcome is actually changeable. Research on learned helplessness also points to the possibility that arousal may assist in recognizing objectively uncertain situations. Harrell and colleagues (1978) found that increasing arousal pharmacologically (using metaraminol) in dogs eliminated the learned helplessness response. Experiencing uncertainty can improve one's ability to deal effectively with the situation.

No Uncertainty: Subjective Certainty and Objective Certainty

Although people may be certain and accurate about a determined situation, it is also possible for an individual to be certain, the outcome to be determined, and the individual to be inaccurate. In one study using trivia questions, participants who reported a 100% probability that their answer was correct were no more correct than participants who reported a 0% probability that they were correct (both groups were correct 20-30% of the time; Fischhoff et al., 1977).

Eyewitness identification is a particularly high-stakes example of the costs of certainty of a wrong answer. When choosing a person from a line-up, confidence is not strongly correlated with accuracy (for a meta-analysis, see Sporer et al., 1995). Further, eye-witness confidence can be increased without increasing accuracy. Confidence can be increased by truth-irrelevant factors such as confirming feedback (Bradfield et al., 2002) and rehearsing one's answers (Wells et al., 1981). Because there is evidence that juries weigh the testimony of assertively certain witnesses more strongly than the testimony of less certain witnesses, artificially decreased uncertainty can potentially lead to the wrong person being punished (Wells et al., 1981; for a review, see Smalarz & Wells, 2013). Inaccurate certainty has even been theorized as contributing to international conflict, with one example being Vice President Cheney expressing "no doubt" that Iraq had weapons of mass destruction (Mitzen & Schweller, 2011). Being certain, but wrong, about a determined outcome can have significant consequences.

Discussion

The present attempt to understand the psychology of situational uncertainty began with the distinction between subjective and objective uncertainty, or what Kahneman and Tversky (1982) dubbed internal and external uncertainty. Subjective uncertainty is the awareness and/or feeling that one lacks crucial information about the situation. Often that information exists out in the world, and uncertainty just means that the person does not know it. Objective uncertainty refers to external events that have not been decided. A given situation may contain either kind of uncertainty, or both, or neither.

Main Findings

The two different kinds of uncertainty suggest different responses would be optimal. Much evidence fits that basic assumption. Agency finds its *raison d'être* [reason for being] in objective uncertainty: When multiple outcomes are possible, the self can often take action to promote the desirable outcomes and avoid the bad ones. Sure enough, many findings indicated that uncertainty increased effort and arousal, consistent with preparing to take action. People sometimes even show preferences for situations with objective **uncertainty** (vis-à-vis objective certainty), presumably because they assume they can help steer the course of events. To be sure, some of these responses extend to irrationality, such as when people act as if they can influence events which in reality they cannot. The preference for betting more on future than past events may reflect an underlying response pattern that assumes objectively undecided events can still be influenced. Likewise, people seem to understand that objective uncertainty entails risk, and their willingness to take risks increases accordingly.

In contrast, when uncertainty is purely subjective, the optimal response would be to suspend direct action and seek information. There was ample evidence to support this pattern also. The quest for information amid subjective uncertainty takes many forms. Attention is drawn to uncertainty. People readily incur costs to reduce uncertainty, and this too extends into the irrational: People will pay to get information that is pragmatically useless or even occasionally counterproductive. They also seek out gratuitously unpleasant information, despite generally advising others in a similar situation not to do so. Some people, at least, respond to

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uncertainty by becoming credulous, indeed becoming more accepting of false and nonsensical information. The greater the uncertainty, the more people want and seek information. These patterns are particularly acute when the objective facts have been determined: People are slightly less eager for immediate information when the situation is also objectively uncertain. Thus, searching for information is highest when uncertainty is purely subjective.

Meanwhile, effortful action may be suspended in the face of subjective uncertainty (much the opposite of objective uncertainty, which calls for action). Multiple lines of work with different procedures showed that experiencing uncertainty leads to reductions in effort. Indeed, some of these were aftereffects measured on a task unrelated to the uncertainty. That is consistent with the view that (subjective) uncertainty causes people to conserve effort and perhaps other resources in general. It seems plausible to speculate that conserving resources would generally be an adaptive response to uncertainty. If one does not know what to expect, then saving up some resources will reduce some of the vulnerabilities. Even in the modern world, when a random crisis hits, it often helps to have money in the bank, or a strong social network, or even just robust health.

The emotional impact of uncertainty is far more complex than we had anticipated when embarking on this review. As already noted, uncertainty tends to increase arousal, which is one component of emotion. Moreover, uncertainty has been shown to intensify and prolong various emotional reactions — including positive ones. There is even some evidence that uncertainty enables emotion to have a stronger influence on judgments and intentions. Uncertainty also makes people more sensitive to reward contingencies and more desirous of rewards. Although uncertainty has a relatively negative reputation, we found evidence of situations in which people are more engaged with uncertain situations than certain ones. People seek out and seemingly enjoy uncertainty in some experiences, including adventures and entertainments. Some amount of uncertainty may be a major sort of “spice of life,” in the colloquial phrase.

Our theory also proposed that people would seek to minimize costly errors by overestimating objective uncertainty. This found very little support. What relevant evidence we found pointed in the opposite direction: People underestimate uncertainty and are overconfident that their views and impressions are correct. Nevertheless, people did seem to respond to objectively uncertain situations by acting as if outcomes were controllable, which would likely accomplish the same benefit (e.g., noticing threats and opportunities).

Implications

Responses to uncertainty seem broadly adaptive but not rationally optimal. Both require explanation.

The usefulness of many responses to uncertainty is evident in much of what we already mentioned. Even when a people’s (lack of) knowledge is the same, people distinguish between situations that are objectively certain and uncertain. With the former, they hold off action and seek information. With the latter, they are more likely to act. Emotions are stimulated and intensified during uncertainty, and that may help sustain cognitive processing and even direct attention toward the most important aspects of the situation. Resources are conserved in a general fashion, which might even end up bringing benefits in different, unrelated situations.

The suboptimal aspects of responses to uncertainty include seeking out pragmatically useless, unpleasant, or even counterproductive information. People also accept various costs in order to get more information, or get it sooner, even when it has no pragmatic value. They may become less critical of and hence embrace false information.

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The combination of seeming adaptiveness without rational optimality supports speculation that the mind adapted to uncertainty early in evolution. That would explain why the responses are simple and crude. They would be helpful even for simple animals, but they would not be sophisticated enough to be optimal for a highly complex human self operating in a society with advanced culture and complex uncertainties.

A recent and powerful version of this theory was proposed by Brosschot, Verkuil, and Thayer (2016). They reversed the standard assumption that the mind starts from a baseline condition of safety and security and only begins to learn about uncertainty (and to regard it as bad) when encountering various threats and dangers. Instead, Brosschot et al. propose that an anxious, stressful condition of uncertainty is a basic property of all living organisms. They say safety is learned, along with a capacity to damp down the anxiety and stress that accompany the normal, default state of uncertainty.

Although Brosschot et al. (2016) offer an extreme version of the theory that minds assume an uncertain environment, it resonates with some patterns in our findings. If safety were default and the dislike of uncertainty were learned because it was mainly associated with threats and dangers, then one would expect a more uniformly negative emotional profile of uncertainty. In contrast, if uncertainty is the default, then the mind may be open to both positive and negative emotions, given that it is important to recognize both good and bad possibilities in the environment. (To be sure, the bad ones are likely more potent and hence take precedence; Tierney & Baumeister, 2019.) As already noted, we found that uncertainty has its emotionally positive side. (It is noteworthy too that the most appealing forms of uncertainty are those that are situated in a highly safe environment, such as a movie theater, or even casino.)

It is possible that some of the pleasure associated with uncertainty derives from the process of reducing uncertainty, like reading or watching a mystery be gradually resolved. Yes, people enjoy movies full of suspense, but they expect the mysteries to be resolved by the end. The entertainment value may derive from the gradual reduction of uncertainty. That would also explain the widespread antipathy toward so-called “spoilers,” that is, people who tell someone how the film ends. If uncertainty reduction were the only goal, then such people would be celebrated, and the term would not be “spoiling.” To maximize pleasure, apparently, the uncertainty must be preserved, at least for a time.

Directions for Future Research

We found general patterns across studies that people’s responses to subjective uncertainty differed based on whether the objective reality was certain or uncertain. However, relatively few studies were designed for direct comparison of the two kinds. Future research may test directly for differences between objectively certain and uncertain situations in terms of impact on effort, behavioral initiative, and information-seeking.

One promising area of future research would be to test for differences in arousal between objective and subjective uncertainty. We review studies that show that people have greater arousal and more enduring emotional responses to uncertain situations than certain situations. For many of these studies, whether the situation was objectively certain or uncertain was unclear. Perceiving a situation as objectively uncertain may increase arousal in comparison to perceiving a situation as objectively certain. Manipulated arousal may even be used to increase the likelihood of perceiving a situation as objectively uncertain.

It is also possible that arousal mobilizes people for different kinds of actions in determined and undetermined situations. For people in determined situations (i.e., objective certainty), arousal associated with (subjective) uncertainty may predict greater information-

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seeking. For people in undetermined situations, in contrast, arousal associated with uncertainty may predict greater effort. Which response arousal activates may depend on the type of uncertainty involved.

The kinds of emotions people experience when they are exposed to objective certainty vs. uncertainty may also be another fruitful line of research. Among people experiencing subjective uncertainty, knowing an outcome is already determined may be associated with decreased feelings of vitality and engagement as compared to knowing it is not determined.

Individual differences likely play a role in how an individual classifies a situation, specifically, whether they experience uncertainty and whether they perceive the situation as determined. Dispositional motivation to achieve certainty, such as need for closure (Kruglanski, 1990), and philosophical beliefs, such as a belief in determinism (Pauhlus & Carey, 2011), may predict tendencies to perceive situations as objectively certain. In addition, future research may profitably study tendencies to overestimate or underestimate uncertainty. Each has drawbacks. Overestimating uncertainty may generate anxiety, while underestimating it might cause one to overlook threats and opportunities.

We covered evidence that people are sometimes overly certain — which could be a maladaptive and costly lack of uncertainty. (In terms of our model, it is a combination of subjective certainty despite objective uncertainty.) Future research may explore this pattern, such as ascertaining whether it is a motivated or purely cognitive bias. Its various causes, mediating processes, and destructive consequences would be worth mapping.

Flourishing and Uncertainty

Uncertainty is a basic fact of life and poses a challenge for positive psychology. How should people flourish in an uncertain world? People, like most organisms, seek to reduce uncertainty in various ways, particularly in terms of cultivating a stable, safe, and satisfying relationship to their environment. The widespread human desire for information, reflected in everything from idle curiosity to the information industry, can be seen as a general strategy for reducing uncertainty.

Nevertheless, our reading of the literature suggests that it would be unwise, impractical, and even quixotic to base coping and flourishing on eliminating uncertainty. At best, efforts at uncertainty reduction can be paired with learning to live with uncertainty, both by tolerating it better and even by cultivating its positive value.

Researchers have long recognized that individuals differ as to tolerance for uncertainty (Dugas, et al., 1998; Freeston et al., 1994). Intolerance is defined by both a desire for certainty and a heightened reluctance or inability to take action amid uncertainty (Birrell et al., 2011). People who are better able to accept uncertainty have better well-being. During the recent COVID pandemic, for example, people with higher tolerance for uncertainty reported higher happiness (Deniz, 2021) and felt better able to live by their personal values (Smith, Twohy, & Smith, 2020). More broadly, people with high tolerance for uncertainty are less likely to experience anxiety disorders and depression than people with low tolerance (Carleton et al., 2012; Carleton, 2014), even when controlling for neuroticism (McEvoy & Mahoney, 2012).

The ability to tolerate uncertainty and to flourish amid uncertainty may be a skill that can be acquired. One relevant line of evidence is that clinical therapy seems able to improve people's tolerance for uncertainty. Mindfulness Based Cognitive Therapy (O'Bryan et al., 2023) and some forms of Cognitive-Behavioral Therapy (Hebert & Dugas, 2019; McEvoy & Erceg-Hurn, 2016; Mahoney & McEvoy, 2012) have been shown to improve tolerance. One form of the latter specifically targets patients' fear and avoidance of uncertain events (CBT-IU; Robichaud, 2013;

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Robichaud et al., 2019). During this therapy, patients are encouraged to experiment with uncertainty (e.g. eating at a new restaurant), and develop awareness of strategies they use to avoid uncertainty (Hebert & Dugas, 2019). By extension, it may be possible to improve the well-being of nonpatients too by helping them accept uncertainty.

Some management theories argue that uncertainty in corporations is better managed by preparing for and accepting it rather than trying to eliminate it (Packard & Clark, 2020). If uncertainty means that one cannot reliably predict the future, it may be more useful to prepare for multiple alternatives — thus accepting the uncertainty rather than fighting or denying it. In parallel, individuals may similarly benefit from being ready for uncertainty. Character strengths such as curiosity, humility, bravery, teamwork, optimism, and humor may help prepare an individual to face inevitable uncertainties (Howell & Sweeny, 2016; Peterson & Seligman, 2004; Sweeny & Andrews, 2014). Experiences such as awe and flow have been shown to decrease anxiety and increase positive emotions during experiences of uncertain waiting (Rankin, Andrews, et al., 2019; Rankin, Walsh, et al., 2020).

Tolerance for uncertainty can extend to a positive appreciation of it — even perhaps to increasing uncertainty under some conditions. Suspense, adventure, competition, romance, and risk add spice to life, in part by enriching the uncertainty. We noted that uncertainty enhances positive emotion as well as adding opportunities for agency. A recent theory suggests people seek their own optimal level of uncertainty, which sometimes requires them to increase uncertainty (Griffin & Grote, 2020). Taking on a new project, asking for critical feedback, or joining a new community group may all support flourishing, but also involve increasing uncertainty.

To be sure, the drawbacks and downsides of uncertainty for well-being are all too familiar (e.g. food insecurity; Frongillo et al., 2017). A moderate level of uncertainty may be optimal for human flourishing. In practice, seeking and cultivating some uncertainty may best be balanced against reducing and conquering it.

Concluding Remarks

Life is unpredictable. It is unpredictable both because no one has complete information and because some outcomes have not been determined yet. People have the opportunity to make the best of uncertain situations by recognizing when situations are uncertain, conserving resources, seeking information they lack, and capitalizing on opportunities to shift undetermined outcomes in desired directions.

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Figure 1

Theorized Optimal Responses to Objective and Subjective Uncertainty