A big data analysis of the relationship between future thinking and decision-making

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We use big data methods to investigate how decision-making might depend on future sightedness (that is, on how far into the future people's thoughts about the future extend). In study 1, we establish a link between future thinking and decision-making at the population level in showing that US states with citizens having relatively far future sightedness, as reflected in their tweets, take fewer risks than citizens in states having relatively near future sightedness. In study 2, we analyze people's tweets to confirm a connection between future sightedness and decision-making at the individual level in showing that people with long future sightedness are more likely to choose larger future rewards over smaller immediate rewards. In study 3, we show that risk taking decreases with increases in future sightedness as reflected in people's tweets. The ability of future sightedness to predict decisions suggests that future sightedness is a relatively stable cognitive characteristic. This implication was supported in an analysis of tweets by over 38,000 people that showed that future sightedness has both state and trait characteristics (study 4). In study 5, we provide evidence for a potential mechanism by which future sightedness can affect decisions in showing that far future sightedness can make the future seem more connected to the present, as reflected in how people refer to the present, past, and future in their tweets over the course of several minutes. Our studies show how big data methods can be applied to naturalistic data to reveal underlying psychological properties and processes.

future thinking | decision-making | big data

Thinking about the future can lead to better decisions. It can lead people to stay in school, save money, and take care of their families and homes. While thinking about the future is clearly adaptive, failures to do so often occur: people regularly gamble, overspend, and eat unhealthy foods. They make decisions that put their physical and psychological health at risk. One way that they may fail to consider the future is by not looking far enough into the future to appreciate what might happen. Good decision-making may depend on a person's future sightedness (that is, on the average length of time into the future that people's thoughts extend) (1). Individuals with relatively far future sightedness may be more likely than those with near future sightedness to factor the future into their decisions, possibly by viewing future events as more connected to the present.

The potential impact of future sightedness on decision-making has been examined in several studies. Near future sightedness has been found to be associated with several kinds of addiction, including alcoholism (2), drug dependence (3), and gambling (4). Far future sightedness has been found to be associated with healthy behaviors, such as investment in long-term savings accounts (5). However, when the relationship between future sightedness and behavior has been investigated directly, the results have been less consistent. Such comparisons have been conducted in what are known as delay discounting tasks, in which people respond to questions such as "Would you prefer $60 today or $100 in 6 mo?" Based on these tasks, it has been found that patients with relatively near future sightedness due to lesions in the ventromedial prefrontal cortex do not necessarily choose smaller immediate rewards than healthy individuals (6). It has also been found that decisions made by healthy individuals do not always follow their level of future sightedness, but interestingly, decisions made by schizophrenics often do follow their level of future sightedness (7). Finally, pathological gamblers who, as expected, tend to choose impulsively on a delay discounting task do not, as expected, have unusually short future sightedness (8).

The inconsistent findings could represent evidence against the role of future sightedness in decision making, or they could reflect a more general issue concerning the measurement of future thinking. Psychological measurements usually involve a scale or prompt in which people are asked to introspect about their own mental states. Despite the well-known limitations of explicit measures, such tasks continue to be used due to the absence of alternative approaches (9, 10). In the case of future sightedness, assessments typically involve use of the Wallace task (1). In this task, people are asked to imagine future events in their life and then report the amount of time until their occurrence. When completing the Wallace task, people often talk about major life events, such as getting married or finishing a degree, and not everyday events, such as going home early or mowing the lawn. People tend to report the kinds of events that they believe the experimenter is most interested in.

One way to avoid the biases associated with the pragmatics of an explicit question-answering task is through an analysis of people's naturally occurring language. A source for such language is what people write on social media websites such as Twitter. On Twitter, individuals share short 140-character messages called "tweets." Many individuals use Twitter (n = 313 million users worldwide), and these users are generally representative of the

Significance

The way that people think about the future can affect their decisions. Our results suggest that individuals who think far into the future make a variety of future-oriented decisions, such as investing in the future and avoiding future harms. Our results also suggest that future thinking may affect decisions by making the future seem more connected to the present. More broadly, our results show the viability of using automated analysis of social media text to measure psychological constructs. Automated analyses of social media are naturalistic (increasing sensitivity to a range of future events), unsolicited (reducing the effects of experimenter prompting), and scalable to millions of tweets generated by tens of thousands of individuals.

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population in terms of gender, education, income, and urban versus rural residence, although Twitter users tend to be younger on average than non-Twitter users (11). Twitter users are often quite prolific (M = 2,324 tweets in our sample) and tweet over long periods of time (M = 2.8 y in our sample). Most tweets are intended to be publicly viewed, although individual users can choose to designate their account as "protected" from public access (10.5% of users in our sample). For our purposes, the advantage of tweets is that they can be analyzed with respect to their references to the future and in particular the length of time to those future events. Unlike explicit scales, tweets are unsolicited and hence free of the potential biases of explicit rating tasks.

The current research uses a large-scale analysis of people's tweets to measure future thinking. In addition to clarifying the relation between future thinking and decision-making, this approach may provide insight into the mechanisms by which future thinking can affect people's behavior. Based on a proposal by Chen (12), we hypothesize that people might be more likely to consider future costs and benefits when they have far rather than near future sightedness, because having far future sightedness may lead them to see the future as more associated with the present. Chen (12) identified a natural linguistic phenomenon that provides evidence for this idea. Languages vary in the degree to which they describe the present and future in the same way. In so-called weak future temporal reference (Weak-FTR) languages, speakers are not required to differentiate the future from the present. In German, for example, one can say, "It rains tomorrow." In strong future temporal reference (Strong-FTR) languages, in contrast, references to the future must be differentiated from references to the present. For example, in English, one needs to use a future indicator, such as the modal verb "will," as in the expression "It will rain tomorrow." Chen (12) found that individuals from communities that speak Weak-FTR languages were more likely to make decisions that seemed to take the future into consideration than individuals from communities that speak Strong-FTR languages. In particular, speakers of Weak-FTR languages save more money, smoke less, and are less obese. According to Chen (12), these behavior patterns are found because speakers of Weak-FTR languages, who do not need to differentiate the present from the future, are invited to view the future as part of their present, making decisions about saving and healthy behavior more immediate to an individual's current decision-making. Similarly, people with far future sightedness might see less difference between the present and the future than those with near future sightedness, because they include more of the future into their present-based decision-making.

Study 1: The Effect of Future Sightedness on Decision-Making in Populations

The hypothesis that decision-making depends on future sightedness should extend beyond the choices of individuals to the collective choices of an entire population. Because various statistics of impulsive and long-range thinking are already available for populations, the first study investigated the relation between future sightedness and collective choices of people living in each of the 50 US states. The general strategy was to collect information about risk taking and investment behavior at the state level and then compare those measurements with the average future sightedness for each state.

Future sightedness was extracted from tweets using the SUTime temporal tagger (13). SUTime is a rule-based temporal tagger built on regular expression patterns. It uses a combination of keywords, such as "tomorrow," and rules, such as "[DATE] at [TIME]," to recognize temporal expressions and convert them into numerical expressions. It processes expressions that refer to absolute dates (e.g., October 30th, 1963), relative times (e.g., last Friday, next week), and mixtures of absolute and relative times (e.g., Tuesday at 4 PM). In the case of relative times, SUTime uses document dates as references. These temporal references can be used to estimate the future sightedness of a tweet: the time at which the tweet was created can be subtracted from the date and time that the tweet refers to. In cases where a tweet refers to more than one future time, future sightedness is given by the average of these references as reflected in the formula $S(t) = \sum_r \frac{M(r)}{n}$, where r is a future temporal reference, $M(r)$ is the number of minutes that the reference projects into the future, and n is the number of temporal references in the tweet. The future sightedness of individual tweets can also be averaged to compute the future sightedness of an individual or population as specified in the formula $S(i) = \sum_t \frac{S(t)}{n}$, where t is an individual tweet and n is the total number of tweets created by an individual.

The SUTime classifier has previously been shown to be quite good at extracting objectively correct time intervals (13). Less clear is whether the future sightedness generated by SUTime reflects people's subjective time intervals. As an initial test of this ability, a study was conducted comparing the time intervals generated by SUTime with those measured by the Wallace task (*Methods*). Pearson correlation indicated that future sightedness as measured by the SUTime tagger correlated positively with future sightedness as measured by the Wallace task: $r(101)$ = 0.205; P = 0.038. The results show that spontaneous language recorded in social media posts can be mined to extract information about people's subjective future sightedness. Additional support for the psychological validity of SUTime was observed in *SI Text*, which found agreement in ratings of future sightedness between SUTime and human raters (*SI Text*).

Interestingly, while people's future sightedness as measured from their tweets correlated with their ratings on the Wallace task, the absolute lengths in time from these two measures differed. The Wallace task indicated a future sightedness on the order of years (M = 459.1 d), whereas people's Twitter posts indicated a future sightedness on the order of days (M = 1.8 d). This shorter future sightedness is in line with the short future sightedness observed in experience sampling studies, in which people are prompted at random times of the day to estimate the average distance into the future of their thoughts (14). This shorter future sightedness could have implications for the relationship between future sightedness and delay discounting. Much work on delay discounting has shown that changes in the degree to which people discount future events are largest for relatively small differences in time between the immediate and delayed rewards (that is, differences on the order of days and weeks) (15–17). Because future sightedness as measured by people's social media posts is similar in scale to the differences in time that have been found to have the greatest impact on delay discounting, people's social media posts may be more suitable than the Wallace task for measuring future sightedness to predict decision-making.

Collective Decision-Making Measures. Two types of collective decision-making, risk taking and investment, were classified by aggregating publicly available data (sources are in *SI Text*). Aggregate data were used to develop a more generalizable measure of risk and investment than would be possible from only a single measure. Risky decision-making was measured as the average z score of binge drinking, drunk driving, drug overdose deaths, teenage pregnancy, and cigarette smoking rates in each US state. Investment decision-making was measured as the average z score of seatbelt use, state park spending, prekindergarten (pre-K) education spending, highway spending, and per-pupil education spending (an analysis that considers

seatbelt use as a measure of risk is in *SI Text*). Tweets from each state were collected from all 50 US states (n = 8,163,153). Future sightedness was determined by averaging the temporal distances into the future automatically generated by the SUTime classifier.

Predictions Regarding Future Sightedness, Future Orientation, and Past Sightedness. Our main hypothesis holds that the impact of future thinking on decision-making depends on future sightedness and not necessarily on, for example, temporal orientation (that is, the proportion of time that people think about the future as opposed to the past). Future orientation was determined by dividing the number of future references by the number of future plus past references as reflected in the formula: $FO = \frac{F}{F+P}$, where F and P are the numbers of tweets from a state that refer to the future and the past, respectively. In addition, our main hypothesis holds that the impact of temporal thinking on decision-making should be restricted to thoughts about the future and not those associated with the past. Thus, we expected decision-making to be related to future sightedness but not past sightedness. A state's past sightedness was determined in the same way as future sightedness but using tweets that referred to the past.

Results. One-way ANOVA indicated that US states differed with respect to future sightedness: $F(45, 268{,}298) = 124.01$; $P < 0.001$. Relative differences in future sightedness are depicted in Fig. 1. To aid in the description of these differences, future sightedness was grouped into nine geographic regions as specified by the US Census Bureau (Pacific, Mountain, West North Central, East North Central, West South Central, East South Central, South Atlantic, Middle Atlantic, New England). As with the states, regions of the United States differed with respect to future sightedness: $F(8,37) = 2.644$; $P = 0.021$. In general, future sightedness was longer on the East and West Coasts than in the middle states. Future sightedness was highest in the New England (M = 1.66 d), South Atlantic (M = 1.56 d), and Pacific (M = 1.42 d) regions. Lower future sightedness was found in regions in the middle of the country, including the Mountain (M = 1.38 d), East South Central (M = 1.35 d), East North Central (M = 1.30 d), West North Central (M = 1.28 d), and West South Central (M = 1.26 d) regions. One exception to this pattern was the Middle Atlantic (M = 1.35 d), which was noticeably lower than the other coastal regions. These results indicate that future sightedness varies across the United States. The overall mean future sightedness in the United States was 1.39 d.

Additional analyses indicated a relation between future sightedness and decision-making, risky decision-making in particular. People in states with far future sightedness took fewer risks than people in states with near future sightedness: $r(44) = -0.513$; $P < 0.001$ (Fig. 2*A*). Looking at the individual variables used in the composite, future sightedness correlated negatively with drunk driving rates [$r(44) = -0.401$; $P = 0.006$] and teenage pregnancy rates [$r(44) = -0.380$; $P = 0.009$] and marginally with cigarette smoking rates [$r(44) = -0.262$; $P = 0.079$].

Additional analyses indicated that the relation between future sightedness and risk taking could not be accounted for by several alternative explanations. One alternative hypothesis is that the relation between future sightedness and risk taking might be explained by various demographic variables such as age, education, gender, race, state gross domestic product, per capita gross domestic product, household income, number of tweets, political orientation, and population size. This turned out not to be the case. On their own, demographic variables were able to account for a significant proportion of the variance in decision-making ($R^2 = 0.518$), but adding future sightedness to the model resulted in a significant increase in variance explained by the model [$R^2 = 0.671$; $F(1,34) = 15.79$; $P < 0.001$]. Another alternative hypothesis is that the relation between future sightedness and risk taking might not have to do with distance in the future per se but rather might relate to the proportion of time that people think about the future as opposed to the past (that is, their temporal orientation). Interestingly, future orientation in particular and future sightedness were both found to be associated with risk-taking behavior but in different ways. As already noted, future sightedness was negatively associated with risk taking. In contrast, future orientation was positively associated with risk taking [$r(44) = 0.548$; $P < 0.001$] and negatively associated with future sightedness [$r(44) = -0.351$; $P = 0.017$]. The results imply that future sightedness has a unique effect on risky behavior and that the relationship between future sightedness and risk taking cannot be reduced to thoughts about the future in general. A third alternative hypothesis is that the relationship between future sightedness and risk taking might not be unique to thoughts about the future but rather, might be due to a general tendency to think distantly into either the future or past. As it turned out, only future sightedness, and not past sightedness, was predictive of risk-taking behavior: $r(44) = -0.150$; $P = 0.318$. Finally, concerns might be raised about the representativeness of the sampling methodology. According to the PEW Foundation (11), the percentages of Twitter users living in rural, urban, and suburban areas are virtually the same, and

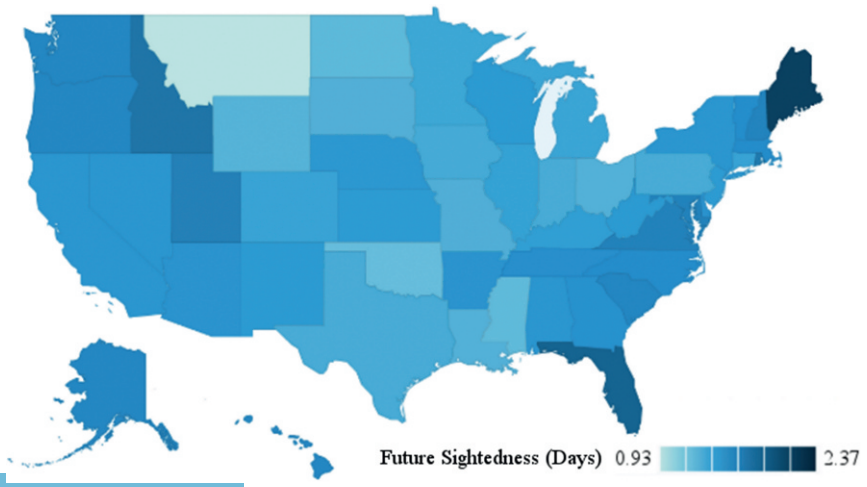

Fig. 1. Future sightedness in days of each US state. Darker colors indicate a longer future sightedness. The color map is log scaled.

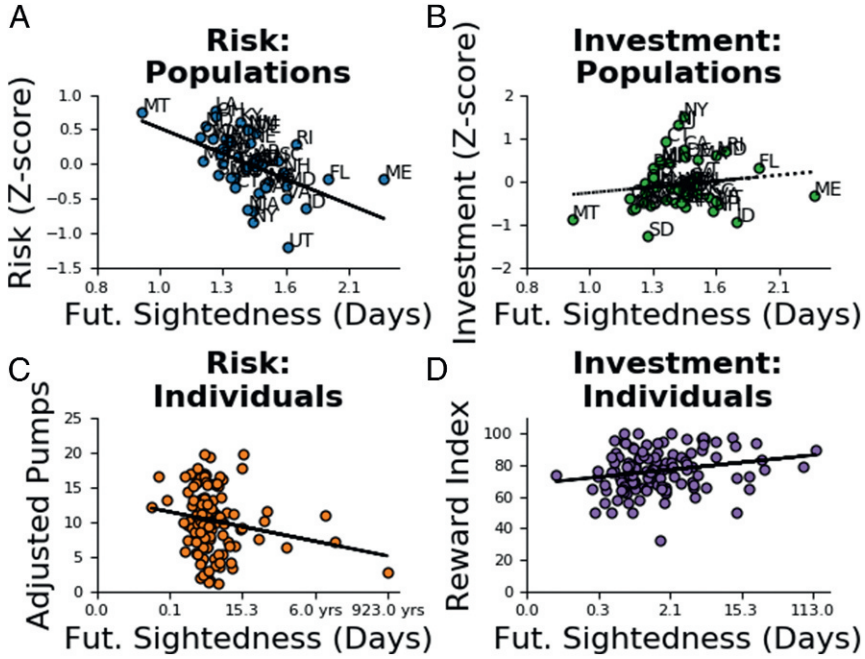

Fig. 2. Relationship between future sightedness and decision-making. (*A* and *B*) Future sightedness and decision-making at the population level (study 1). (*C* and *D*) Future sightedness and decision-making at the individual level (studies 2 and 3). Horizontal axes are log scaled.

therefore, it is likely that our sampling methodology was relatively representative with respect to at least these three kinds of communities. There is also reason to believe that the results were not due to a chance sampling of the population. A split-half analysis of the future sightedness of each state revealed a very high correlation of $r = 0.979$ between the halves, implying that the results are not specific to our particular sampling of the population.

While significant relations were found between future sightedness and risk taking, significant associations were not found between future sightedness and investment behavior. There was no evidence that states with far future sightedness invested more in the future as represented by seatbelt use, state park spending, pre-K education spending, highway spending, and per-pupil education spending: $r(44) = 0.147$; $P = 0.329$ (Fig. 2*B*). The failure to find evidence of a relationship between future sightedness and investment might indicate the absence of such a relationship. However, findings at the population level do not always hold at the level of individuals, a phenomenon sometimes referred to as the ecological fallacy (18). For example, immigrants have lower literacy rates, but US states with more immigrants have higher literacy rates. This surprising difference is likely due to the tendency of immigrants to move to areas with high literacy rates (19). In this study, it is possible that the relation between future sightedness and investment behavior was obscured by other factors driving investment behavior at the state level. Such alternative causal factors can better be controlled by going beyond populations to the level of individuals.

Study 2: The Effect of Future Sightedness on Decision-Making in Individuals: Investment

If future sightedness affects decision-making, then the effect should be present not only for risk taking but also in the allocation of resources for the purpose of investment. An association between future sightedness and investment behavior was not found in study 1, but the failure to find a relationship in this study may have been due to the analyses being done at the population level. This study investigated the possible relation between future sightedness and decision-making at the level of individuals. One way to measure an individual's tendency to invest is to examine their willingness to wait for larger rewards in a delay discounting task (Fig. 3). To the extent that investment behavior is associated with future sightedness, an individual's tendency to forgo short-term rewards for larger long-term rewards should be associated with their tendency to look far into the future.

Participants were recruited via Amazon Mechanical Turk, a website where individuals can complete psychology experiments as well as other internet-based tasks for payment. Participants on Mechanical Turk are generally diverse in race, gender, education, and income levels (20, 21). A variety of psychological effects have been successfully replicated on Mechanical Turk (22), including studies of decision-making (23).

Participants whose tweets could not be accessed ($n = 22$) or whose future sightedness could not be calculated, because their tweets contained no past or future references ($n = 48$) or contained past but no future references ($n = 4$), were excluded from the analysis of future sightedness. As predicted, people's decision-making tendencies were reflected in their future sightedness. As depicted in Fig. 2*D* and as predicted, individuals with far future sightedness were more likely to wait for future rewards than those with near future sightedness: $r(122) = 0.222$; $P = 0.013$. Because individual level data were used, the results rule out the potential for an ecological fallacy based on population

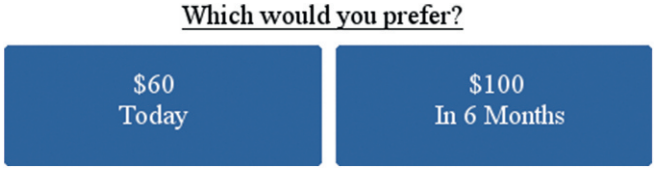

Fig. 3. A sample delay discounting trial. In this trial, the participant is asked to choose between $60 today and $100 after a delay of 6 mo.

data alone. In line with previous delay discounting tasks, the average reward index was 76.28 (24, 25).

Follow-up analyses ruled out two alternative explanations for the relationship between future sightedness and investment. The relation between future sightedness and investment is uniquely associated with thoughts about the future. In particular, there was no evidence that discounting could be explained by past sightedness: $r(126) = 0.114$; $P = 0.202$. Also important, not all thoughts about the future were relevant to predicting investment behavior. Future orientation (that is, the tendency to think about the future as opposed to the past) was not associated with investment behavior [$r(126) = 0.052$; $P = 0.557$], indicating that investment behavior depends on how far an individual thinks into the future and not their tendency to think about the future in general. The results differ from those in study 1, in which evidence for a relation between future sightedness and investment behavior was not found. The reason why such evidence may have emerged in this study is because studies at the level of individuals allow for greater control of potentially confounding variables.

Study 3: The Effect of Future Sightedness on Decision-Making in Individuals: Risk Taking

In study 1, future sightedness was found to be negatively associated with risk taking at the population level. This study investigated this relation at the level of individuals. If future sightedness affects decision-making with respect to risks, then individuals with far future sightedness should be less likely than those with short future sightedness to behave in a way that makes them vulnerable to future costs.

In study 3, risky behavior was measured using the Balloon Analogue Risk Task (BART) (26). In this task (Fig. 4), participants are presented with a series of opportunities to earn money by inflating a balloon. Participants can earn real money every time that they inflate the balloon, but they also take a risk in doing so, because each inflation can lead to the balloon popping, resulting in no money earned for that trial. If participants stop inflating before the balloon pops, they can bank the money that they have earned and proceed to the next trial. Amazon Mechanical Turk workers ($n = 154$) completed an online version of the BART (27). Participants also provided their Twitter username, which was used to access their tweets and classify their future sightedness.

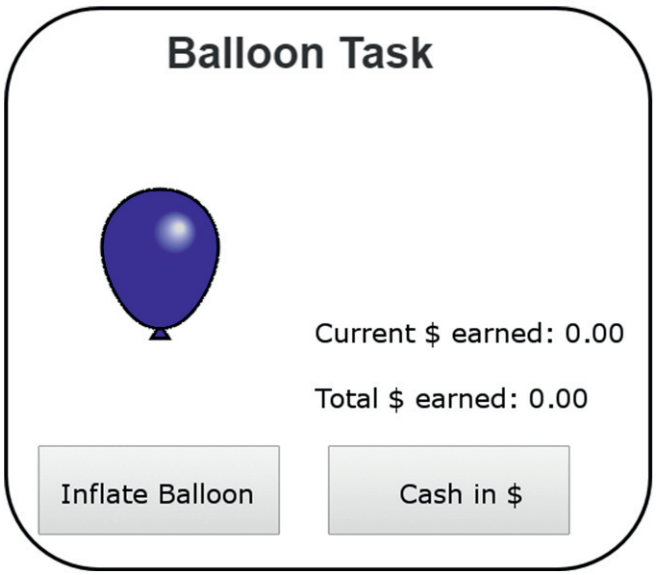

Fig. 4. The BART. Participants' goal is to earn money by inflating a series of 20 balloons. Participants can click "inflate balloon" to earn money or "cash in $" to proceed to the next trial. However, if the participant clicks inflate balloon, the balloon may instead pop, causing the participant to lose all money earned for the trial.

Participants were excluded from the analysis if they did not complete the task ($n = 3$), had tweets that could not be accessed ($n = 21$), or had tweets without any reference to the future that could be detected by SUTime ($n = 6$). A scatterplot of the results is depicted in Fig. 2*C*. As predicted, future sightedness was negatively associated with risk taking [$r(122) = -0.190$; $P = 0.035$], implying that individuals with far future sightedness took fewer risks than those with near future sightedness. Follow-up analyses ruled out three alternative explanations for the results. First, the relation between future sightedness and risk taking was unique to thoughts about the future; there was no evidence of a relation between risking taking and past sightedness: $r(121) = -0.041$; $P = 0.650$. Second, the association between future sightedness and risk taking was associated with how far people's thoughts extended into the future; future orientation, as measured by the proportions of time that people's tweets were about the future as opposed to the past, was not associated with risk taking: $r(122) = 0.051$; $P = 0.574$. Third, linear regression revealed that, while gender and age explained some variance in risk taking ($R^2 = 0.072$), adding future sightedness to the model significantly increased the variance explained [$R^2 = 0.137$; $F(1,115) = 8.559$; $P = 0.004$]. In sum, the results provide further support for the hypothesis that the effect of future thinking on decision-making depends on how far into the future people's thoughts about the future extend.

Study 4: Future Sightedness as a Cognitive Characteristic

The results from studies 2 and 3 imply that how one thinks about the future is a relatively stable characteristic of one's psychology. This is implied by the findings that people's decisions in these previous studies could be predicted from their past writings. Psychological characteristics that are relatively stable have been studied extensively with respect to personality and intelligence (28–31). The findings here point to another kind of psychological characteristic, a cognitive characteristic, concerning how people think about the future.

Whereas the results from studies 2 and 3 imply psychological stability, the results from study 1 point to psychological variability. In study 1, future sightedness was found to associated with where one lives, suggesting that future sightedness might depend, in part, on contextual factors. It seems then that an analysis of the stability of a person's future sightedness would likely reveal that future sightedness has both trait- and state-like properties.

The state and trait properties of future sightedness can be studied through an analysis of people's tweets. In particular, if future sightedness is a trait, then the average difference in future sightedness between two tweets should be smaller when those two tweets are sampled from the same individual than when they are sampled from different individuals. However, to the extent that future sightedness is a state, then the difference in future sightedness between two tweets should be larger as the distance in time increases.

These predictions were tested by compiling multiple years' worth of tweets from a large number of people ($n = 90{,}063{,}490$ tweets from 38,655 individuals) and analyzing the variation in future sightedness within and between individuals.

The results indicated that future sightedness has both trait and state properties. In support of future sightedness being a trait and as shown in Fig. 5*A*, the average difference in future sightedness for sets of tweets drawn from the same individual ($M = 4.2$, SD $= 1.0$) was less than the average difference between sets of tweets drawn from different individuals ($M = 4.9$,

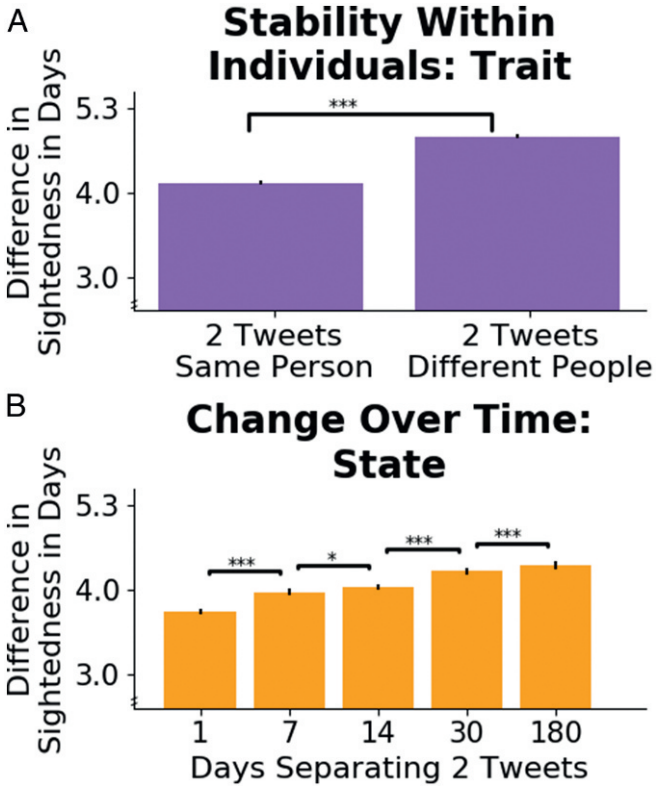

Fig. 5. Stability of future sightedness (study 4). The vertical axis plots the average difference in future sightedness between pairs of tweets created by the same versus different individuals (*A*) and between pairs of tweets created by the same individual separated by different distances in time (*B*). Error bars indicate 95% confidence intervals. Vertical axes are log scaled. $*P < 0.05$; $***P < 0.001$.

SD = 1.4) [$t(15{,}582) = 38.90$; $P < 0.001$]. This trait effect could not explained by a difference in the calendar dates from which tweets within and between individuals were drawn. No difference was observed in the calendar dates of pairs of tweets within vs. between individuals: $t(15{,}582) = 0.573$; $P = 0.567$. In support of future sightedness being a state and as shown in Fig. 5*B*, the average difference in future sightedness increased as the time between the tweets (1, 7, 14, 30, and 180 d) increased. Planned contrasts indicated significant differences between all adjacent intervals of time. Tweets were more similar when separated by 1 than 7 d [$t(22{,}196) = 10.83$; $P < 0.001$], more similar when separated by 7 than 14 d [$t(20{,}570) = 2.39$; $P = 0.017$], more similar when separated by 14 than 30 d [$t(19{,}507) = 9.99$; $P < 0.001$], and more similar when separated by 30 than 180 d [$t(14{,}704) = 5.87$; $P < 0.001$].

The results support one of the main findings implied in studies 2 and 3: that future sightedness is, in part, a cognitive characteristic (that is, a property of people's cognition that is relatively consistent over time). The results show that future sightedness is also a state. Within an individual, future sightedness was more similar the closer together that tweets were created in time. This result is consistent with reports of successful interventions designed to increase future sightedness, which have been shown to affect behaviors, such as investment in long-term savings accounts (5).

Study 5: Why Does Future Sightedness Affect Decision-Making?

While several studies have shown that future sightedness can affect decision making, the precise reason why is unclear. One possibility is that far future sightedness leads people to see the future as more connected to the present. If this is the case, the choice between "$10 today" and "$20 in 1 mo" reduces to a choice between "$10 in the present" and "$20 in the present," in which case the larger option will be more attractive.

One way to assess the extent to which an individual views the future as associated with the present is to determine the degree to which references to the present "prime" references to the future. In the original work on semantic priming, it was found that people were faster to decide that a string of letters was a word when the word was preceded by an associated word (32). For example, people were faster to recognize the word doctor when it was preceded by the word nurse than when it was preceded by the word bread (32). The effect was interpreted as due to the spreading of activation from one word to neighboring words, which facilitated the process of recognition. A related effect might occur in the case of neighboring tweets. When people talk about a particular topic, it might raise the possibility that other topics will be mentioned soon after. In the case of temporal orientation, references to the present might prime additional references to the present. To the extent that the future is associated with the present, references to the present should also prime references to the future. If having far future sightedness makes the future more associated with the present, then such priming effects should be stronger for those having far than near future sightedness. These predictions were tested by identifying tweets that referred to the present. The tweets that followed within 3 min of that tweet were examined for the proportions of times that they mentioned the past, present, and future. These likelihoods were compared with the likelihood of past, present, and future references in tweets not occurring within 3 min of a present reference.

The proportions of times that people referred to the past, present, and future differed after they tweeted about the present: $F(2{,}58{,}692) = 233.50$; $P < 0.001$. Pairwise comparisons using a Bonferroni correction indicate several more specific effects.

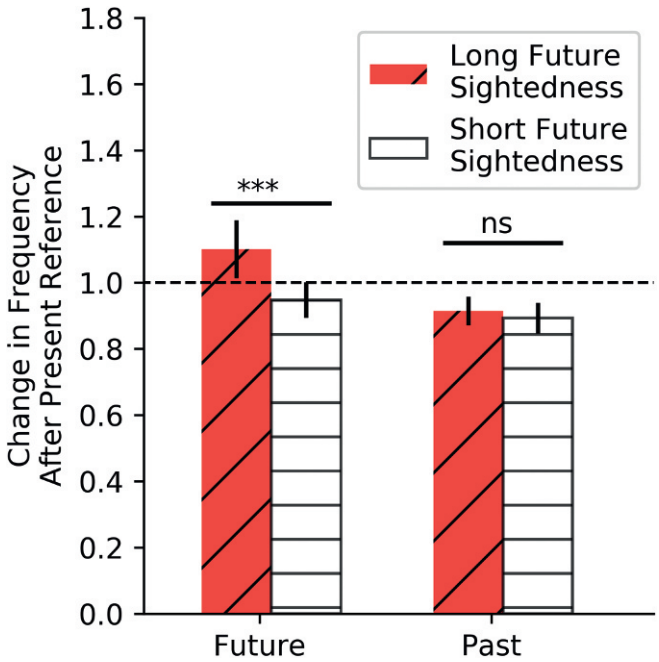

Fig. 6. Frequency of temporal references 0–3 min after an individual references the present. The horizontal line represents no change, and values above the line represent increases in frequency. Error bars indicate 95% confidence intervals. $***P < 0.001$; ns, not significant.

Not surprisingly, after talking about the present, individuals were more likely to refer to the present than either the future [$t(29{,}383) = 15.01$; $P < 0.001$] or the past [$t(29{,}358) = 15.71$; $P < 0.001$]. The finding that references to the present are associated with other references to the present more than they are associated with references to the future or past is exactly what would be predicted by a priming effect. Of critical interest to the main hypothesis, after tweeting about the present, individuals were more likely to tweet about the future than the past [$t(29{,}349) = 4.28$; $P < 0.001$], implying a tighter relationship between the present and the future than between the present and the past.

As expected and as shown in Fig. 6, the probability of referring to the future after referring to the present differed as a function of an individual's future sightedness. Individuals with far future sightedness were significantly more likely to reference the future than were individuals with near future sightedness: $t(29{,}386) = 3.00$; $P = 0.003$. Consistent with this finding, references to the future increased over chance levels for those with far future sightedness [$t(14{,}430) = 2.30$; $P = 0.021$] but not for those with near future sightedness [$t(14{,}956) = -1.94$; $P = 0.053$]. This result was not explained by a general increase in temporal references in individuals with far future sightedness. Individuals with far future sightedness were no more likely to refer to the past [$t(29{,}360) = 0.67$; $P = 0.504$] or present [$t(29{,}397) = 1.103$; $P = 0.270$] after referring to the present.

The results support the hypothesis that the relation between future thinking and decision-making depends on future sightedness. Thinking far into the future leads people to see the present as more associated with the future. One potential explanation for why this should be the case is that future sightedness forges a connection between the present and the future with respect to concreteness. This idea is reflected in Construal Level Theory (33, 34). Construal Level Theory hypothesizes that, as events become more distant in time, they are construed more abstractly. To test this hypothesis, we reanalyzed the corpus of tweets in study 5 with respect to the predictions of Construal Level Theory. This was accomplished using concreteness ratings of 40,000 English lemmas (35). The analysis yielded two main findings. First, we found that, as tweets became more distant from the present, they became less concrete: $r(10{,}086{,}705) = 0.052$; $P < 0.001$. Second, we found that those with far future sightedness talked less concretely about the present than those with near future sightedness: $t(33{,}823) = 2.44$; $P = 0.015$. These results are consistent with a Construal Level Theory account of our priming effect. Given that thoughts about the future become less concrete with distance into the future, the point where the level of abstractness in the present matches the level of abstractness in the future will tend to be farther into the future (and past) for those with far future sightedness than for those with near future sightedness. However, critical to this explanation is the preliminary finding that people with far future sightedness tend to construe the present more abstractly than those with near future sightedness. This surprising phenomenon certainly deserves further examination.

Our results support the hypothesis that individuals with far future sightedness see the future as more connected to the present than do individuals with near future sightedness. In the course of ordinary language, when an individual refers more often to the present, they are also more likely to refer to the future but not the past. Additionally, after a present reference, individuals are more likely to refer to the future than to the past. This effect is stronger for individuals with far future sightedness, suggesting that those with far future sightedness see the future as more connected to the present than do those with near future sightedness.

General Discussion

The results support the hypothesis that the way that people think about the future has an impact on their decision-making. At the level of populations, US states that think farther into the future were less likely to engage in risky decision-making. At the level of individuals, individuals who think farther into the future were more likely to invest in the future and less likely to engage in risky decision-making.

The future sightedness observed in individuals' tweets was short, usually on the order of days. This finding differs from prior work in which future sightedness was much longer: on the order of years (1, 6, 7). One reason for this difference may be that prior work explicitly asked individuals to retrieve future events, whereas this study used an implicit measure of future sightedness. The implicit measure, which resulted in shorter future sightedness, was seemingly more predictive of behavior than the explicit measure of future sightedness.

Across studies 1–3, future sightedness was found to have a specific effect on decision-making. In study 1, in particular, future sightedness and future orientation patterned differently: far sightedness was associated with low risk taking, while high future orientation was associated with high risk taking. This difference between future orientation and sightedness is quite interesting. The association between future sightedness and risk taking is not especially surprising. Risk typically has two parts: a short-term reward and a potential long-term cost. For example, cigarette smoking provides pleasure in the near future but a health risk in the much longer future. Those who tend to look far into the future may tend to weigh the cost part of risk taking more than those who do not tend to look far into the future, and this could make them more risk averse. Less clear is the positive relation between future orientation and risk taking (that is, why a tendency to think about the future is associated with risk taking). One detail that may help to explain this association is the finding from study 1 that high future orientation is negatively associated with future sightedness (that is, those who tended to think about the future tended to look less far into it). Given this negative association, the reason why a tendency toward the future might be associated with risk taking is because those who tend to think about the future will tend to focus on the near future, which in the case of risks, involves focusing on the rewards, likely promoting risk taking. Such an explanation leaves unexplained, however, why high future orientation is negatively associated with distance into the future. At the risk of being circular, people who are interested in the future might be those who wish to escape their circumstances and are in search of rewards in the near term. Clearly, this curious and interesting set of relations is deserving of additional attention.

While the future sightedness observed in tweets was quite short, it was also predictive of individuals' future sightedness in a behavioral task and of individuals' decisions. The results of study 4 suggest one reason why this may have been the case. The results of study 4 suggest that future sightedness is, in part, a stable characteristic of individuals. However, the results also suggest that future sightedness is, to some extent, a changeable state. This pattern of results suggests that future sightedness may be modified across different contexts. For example, Twitter may induce relatively near future sightedness due to the tendency to tweet about more ordinary life events, while laboratory tasks may induce relatively far future sightedness due to the pragmatics of the question-answering situation. While future sightedness may be modified by context, the finding that future sightedness is also a trait explains why it should be correlated within an individual across such contexts.

The results from study 5 suggest a potential mechanism for the impact of future sightedness on decision making. Tweets about the present were more likely to be followed by tweets about

the future for those with far than near future sightedness. This finding suggests that having far future sightedness is associated with seeing the future as connected to the present. One way that the future might be viewed as connected to the present is in terms of vividness. Having far future sightedness may cause the future to be more vivid. Supporting this account, vividly imagining the future, either via episodic future thinking or interacting with the future self in virtual reality, has been associated with future-oriented decision-making in a delay discounting task (25, 36, 37). A second possibility is that far future sightedness causes the future to be more associated with the present and thus, more likely considered in present decision-making. Supporting this account, making future rewards more salient by emphasizing the "hidden $0" in the future gained by choosing a present reward makes individuals choose more patiently in a delay discounting task (38, 39).

People often act impulsively. They eat unhealthy foods, gamble, and overspend. Such shortsighted behaviors are clearly maladaptive, but they often persist. The results of this research offer some insight into why such behaviors might occur: a person's tendency to think shortsightedly depends, in part, on stable characteristics of their cognition. The results also indicate, however, that future sightedness can be influenced by context. This malleability opens up possibilities for bringing about positive change. To the extent that future sightedness can be extended, it may allow for the kinds of long-term decisions that lead to healthier lives.

Methods

A brief description of methods is available in this section, and a more extended description is available in *SI Text*. All methods used were approved by the Emory University Institutional Review Board; participants gave informed consent and could opt out of the study at any time.

Evaluation of SUTime Classifier. Amazon Mechanical Turk workers (n = 131) completed the Wallace task to determine their future sightedness. Participants generated 10 events that "may happen to you in the future" and rated the distance of these events in the future in days, hours, and minutes. The dependent measure was the mean extension (1, 6, 7) (i.e., the average future sightedness of these events). Participants also provided their Twitter username, which was used to obtain their tweets (up to 3,200 most recent tweets). The future sightedness of these tweets was classified using SUTime. Data from 28 participants could not be analyzed, because their tweets could not be accessed (n = 10), their tweets contained no future references (n = 7), or their Twitter-based future sightedness was outside a standard leverage cutoff (leverage $> 2p/n$; n = 11) (40).

Study 2: Delay Discounting Task. Amazon Mechanical Turk workers (n = 198) completed a delay discounting task, which fully crossed six delay lengths (1 wk, 6 mo, 1 y, 5 y, 10 y, 20 y) with 10 immediate reward amounts ($1, $5, $10, $20, $40, $60, $80, $90, $95, and $99) for 60 trials presented in random order. The delayed reward was always $100. For example, on one trial, participants chose between $60 today and $100 in 6 mo (Fig. 3). Delay discounting was measured using the reward index: $RewardIndex = 100 \times \frac{TotalRewardObtained}{MaximumPossibleReward}$ (24, 25).

Study 3: BART. Participants completed a 20-trial version of the BART using a publicly available JavaScript implementation (27). Balloon explosion points were drawn from a uniform distribution from 1 to 32 clicks. Participants earned a bonus of $0.005 per click on trials where the balloon did not explode. The dependent measure was a participant's adjusted pumps (26) defined as the mean number of times that participants inflated a balloon per trial, excluding trials where the balloon exploded. The average adjusted pumps score was 10.16 pumps. Participants also provided their age and gender (n = 5 declined to provide their age).

Studies 4 and 5: Corpus Acquisition. In total, 90,063,490 tweets spanning 9.46 y were obtained from 38,655 individuals (M = 2,330 tweets per individual). Individuals were selected using random three- and four-digit strings of letters and numbers to retrieve Twitter usernames in batches of 20. Usernames that did not designate English as their primary language or contained URLs in their user profile (a frequent marker of corporate accounts) were discarded. For the remaining usernames, all tweets associated with that username (up to the most recent 3,200 tweets) were retrieved and classified for future sightedness.

Study 4: Selection of Data Used to Investigate Trait Effects. If future sightedness is a trait, then future sightedness should be more consistent within individuals than across individuals. To assess this possibility, random samples were drawn of groups of tweets created by the same individual and compared with groups of tweets created by different individuals. Within-individual differences in future sightedness were determined by selecting without replacement two sets of 50 tweets tagged with a future sightedness. Between-individual differences in future sightedness were determined by selecting without replacement a set of 50 tweets from an individual and then selecting a second set of 50 tweets from a second individual. The second individual was selected by choosing the username alphabetically closest to the first username containing at least 50 tweets; 15,583 usernames met these requirements.

Study 4: Selection of Data Used to Investigate State Effects. If future sightedness is a state, then future sightedness should be more consistent across short than long periods of time. This possibility was assessed by retrieving from each individual five pairs of 50 tweets differing by one of five distances (1, 7, 14, 30, and 180 d). For each distance, the average absolute value of the difference in future sightedness between pairs of tweets was calculated.

Study 5: Temporal Reference Classification. The corpus from study 4 was used. For each individual in the corpus, temporal references were identified using SUTime. The proportions of past, present, and future references were counted (*i*) in tweets occurring 0–5 min after a present reference and (*ii*) in all other tweets. The dependent measures were the proportions of past, present, and future references occurring 0–5 min after a present reference divided by the proportions of these references not occurring after a present reference.

Study 5: Future Sightedness Classification. The future sightedness of each individual in the corpus was identified using SUTime. Individuals with near and far future sightedness were identified by a median split.

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