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Texting while driving as impulsive choice: A behavioral economic analysis

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ABSTRACT

The goal of the present study was to examine the utility of a behavioral economic analysis to investigate the role of delay discounting in texting while driving. A sample of 147 college students completed a survey to assess how frequently they send and read text messages while driving. Based on this information, students were assigned to one of two groups: 19 students who frequently text while driving and 19 matched-control students who infrequently text while driving but were similar in gender, age, years of education, and years driving. The groups were compared on the extent to which they discounted, or devalued, delayed hypothetical monetary rewards using a delay-discounting task. In this task, students made repeated choices between $1000 available after a delay (ranging from 1 week to 10 years) and an equal or lesser amount of money available immediately. The results show that the students who frequently text while driving discounted delayed rewards at a greater rate than the matched control students. The study supports the conclusions that texting while driving is fundamentally an impulsive choice made by drivers, and that a behavioral economic approach may be a useful research tool for investigating the decision-making processes underlying risky behaviors.

1. Introduction

It has been widely recognized that texting while driving is a global safety issue in traffic injury and fatalities. In the United States, for example, the National Safety Council (2014) estimated that 5–14% of motor vehicle crashes, or 281,000–786,000 crashes per year, are attributed to texting while driving. According to the 2012 National Occupant Protection Use Survey (NOPUS), which provides the only nationwide probability-based observed data in the United States, 1.5% of drivers were observed to be texting or visibly manipulating hand-held devices while driving (Pickrell, 2014). The percentage is twice as high as the average in younger drivers (age 16–24), and the number generally has been rising since the survey started in 2005. The prevalence is similar in Australia (Young et al., 2010). Among college students in the United States, self-reported estimates of the prevalence of texting while driving revealed high frequencies of such behavior, ranging 74–92% among those surveyed (Atchley et al., 2011; Cook and Jones, 2011; Harrison, 2011).

To date, legislation to prohibit drivers from texting while driving has been adopted by 44 states in the U.S. and the District of Columbia, and it is a primary offense in all but five of those states (Governors Highway Safety Association, 2015). Despite widespread support among the general public and legislators, laws banning texting while driving are difficult to enforce (Gauld et al., 2014). To further complicate matters, evidence for the effectiveness of these laws in preventing texting while driving is mixed. Studies show that texting bans are not associated with reductions in the rate of texting while driving (Goodwin et al., 2012) or motor vehicle crashes (Ehsani et al., 2014). Indeed, Ehsani et al. observed a small but statistically significant *increase* in crash rate following the introduction of Michigan's texting restriction for all drivers. The authors posited that an increased crash risk might be due to a shift in drivers' texting behavior toward a more dangerous, concealed manner, resulting in increased duration of eye gazes away from the road (Simons-Morton et al., 2014).

Educational campaigns that increase awareness of the dangers of texting while driving are other strategies used to prevent texting while driving (e.g., Sherin et al., 2014). The rationale supporting the promotion of educational campaigns is the assumption that drivers lack relevant knowledge or awareness of the dangers of texting while driving. Since 2009, the U.S. Department of Transportation has launched various campaigns to increase the

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awareness of the dangers. In 2014, the National Highway Traffic Safety Administration (NHTSA) launched the first national highly visible enforcement and media campaign *U Drive. U Text. U Pay.*, which was supported by television, radio and digital advertising (NHTSA, 2015). Despite these efforts, however, it is unclear whether awareness of the dangers is sufficient to decrease actual texting behavior. For example, Atchley et al. (2011) found that awareness of the risks of texting while driving only weakly predicted avoidance of the behavior. Indeed, Ginsburg et al. (2008) found that teenagers, who engage in risky driving behaviors, including texting while driving, tend to believe they are less of a safety risk than teenagers who do not engage in such behaviors. Atchley et al. reported a similar finding and claimed that texting while driving alters the attitude toward texting through a reduction in *cognitive dissonance* (Festinger, 1957). Although there is little doubt that legislation and educational campaigns regarding texting while driving are worthwhile, the empirical evidence, when taken together, suggests that these efforts may need to be supplemented with other approaches to be maximally effective.

One approach is to examine the factors that give rise to texting behavior in the first place. Several studies, focused on investigating the psychological factors, identified several different personality traits that predict texting while driving. For example, texting while driving has been linked with the impulsivity-like personality trait of negative urgency, which refers to "the tendency to act impulsively when experiencing negative affect" (Pearson et al., 2013, p. 142), low levels of mindfulness (Feldman et al., 2011), habitual texting tendencies (Bayer and Campbell, 2012), cell phone dependence (Struckman-Johnson et al., 2015), perceived texting distractibility (only for males; Struckman-Johnson et al., 2015), and risky behavior tendencies (only for females; Struckman-Johnson et al., 2015). Finally, consistent with the theory of planned behavior (Ajzen, 1991), Nemme and White (2010) found that drivers' intentions to text while driving, which are influenced by personal attitudes, subjective norms, perceived control, reference group norms, and morality norms, effectively predict actual behavior of texting while driving.

It is important to note, however, that many psychological investigations rely on measures that are subjective in nature and rely entirely on individuals' self-evaluation of their own behaviors, sometimes across many different settings over long periods of time (Spinella, 2005). Although self-report measures are generally accepted as valid instruments to assess various personality traits such as impulsivity (Loree et al., 2014), more objective, behavioral measures may be useful complements to capture different dimensions of psychological phenomena without relying on individuals to accurately characterize their own behavior (Ledgerwood et al., 2009). Furthermore, although the results based on self-report measures may offer predictive utility in classifying individuals at risk for texting while driving, they do not greatly contribute to a better understanding or characterization of the underlying behavioral or cognitive processes. Methods that use more objective, behavior-based measures may overcome some of these limitations. One promising research and conceptual strategy is to employ a behavioral economic approach.

Behavioral economics refers to "the application of economic concepts and approaches to the molar study of individuals' choices and decisions" (Bickel et al., 2014a, p. 643). From a behavioral economic perspective, texting while driving may be conceptualized as a tendency toward *impulsive choice*, which is defined as choosing smaller immediate rewards over larger delayed rewards (Rachlin and Green, 1972). That is, texting while driving involves a trade-off between immediate and delayed outcomes, and it manifests behaviorally as a preference for smaller immediate rewards (e.g., short text messages while driving) over larger delayed rewards (e.g., a longer conversation sometime later when not driving).

Instead of viewing impulsive choice as manifestations of "irrational" decision-making, a behavioral economic approach posits that an impulsive choice is made because the subjective value of a delayed reward is *discounted* as a function of the time to its receipt (see Green and Myerson, 2004, for review). The process by which the decision maker subjectively devalues future events is termed *delay discounting* (Madden and Bickel, 2010). Delay discounting is one of the central principles in behavioral economics (Bickel and Marsch, 2001), and it serves as an index of an individual's preference for small immediate rewards over large delayed rewards, akin to the difficulty of delaying gratification (MacKillop et al., 2011).

Delay discounting is also considered to underlie other forms of impulsive decision making, and the process is highly relevant to a range of impulse control and addictive disorders (Madden and Bickel, 2010). For example, numerous research studies have shown that delay discounting plays a critical role in impulsivity-related problems, including but not limited to substance dependence and abuse (e.g., MacKillop et al., 2011), obesity (e.g., Bickel et al., 2014c), pathological gambling (e.g., Dixon et al., 2003), internet addiction (e.g., Saville et al., 2010), risky sexual behavior (e.g., Chesson et al., 2006), and criminal behavior (e.g., Arantes et al., 2013). Texting while driving shares some key features with addictive, risky, and criminal behaviors in that it also involves trade-offs between small, immediate outcomes and large, delayed ones.

Studies on delay discounting with human participants (e.g., Rachlin et al., 1991) are similar to psychophysical experiments (Richards et al., 1997). In the typical procedure, participants are exposed to a series of choice trials in which they choose between receiving a smaller reward available immediately (e.g., $800 right now) and a larger reward available after a delay (e.g., $1000 in 1 year). Across the series of the choice trials, the amount of the smaller immediate reward is adjusted to identify the point at which the participant switches their preference from the larger delayed reward to the smaller immediate reward. This switching point indicates a *point of indifference*, where the subjective value of the smaller immediate reward and the larger delayed reward are equivalent. The series of choices is repeated across several delays, yielding indifference points that decrease as the delays increase.

Numerous previous studies have found that the hyperbolic function developed by Mazur (1987) well describes the devaluation or discounting of a reward as a function of delay:

$$V_d = \frac{A}{1 + kD'} \quad (1)$$

where V_d refers to the subjective or discounted value of a delayed reward, A refers to the reward amount, D refers to the delay to the reward, and k is an empirically derived parameter that reflects the rate of discounting. The higher k values indicate greater discounting and thus greater impulsivity (e.g., Bickel and Marsch, 2001).

To date, only one study has investigated delay discounting in the context of texting. Atchley and Warden (2012) investigated whether the subjective value of a combination of hypothetical monetary rewards and hypothetical opportunities to reply to a text message is hyperbolically discounted as a function of delay to reply. In one scenario of their study, college students chose between one alternative of receiving a smaller amount of money (e.g., $5.00) and replying to a text message immediately and another alternative of receiving a larger amount of money ($100) and delaying a reply (e.g., 60 min). They found that the subjective value of the combined rewards was hyperbolically discounted as a function of delay to reply.

Although Atchley and Warden (2012) study demonstrated that delay discounting methods can provide insights related to individuals' decision making in some texting scenarios, it remains to be seen whether a measure of delay discounting differentiates drivers who frequently text while driving and drivers who do not

Table 1
Demographic characteristics for TWD and Non-TWD groups.

Characteristics	TWD	Non-TWD
N	19	19
Gender		
Male	12	12
Female	7	7
Age in years[a]	19.3 (2.59)	19.1 (1.89)
Years of higher education[a]	1.4 (1.13)	1.4 (0.59)
Years driving[a]	2.7 (1.52)	2.7 (2.00)
Frequency of TWD[a]	5.6 (0.71)	2.1 (0.72)
Perceived danger of TWD[a]	6.0 (1.18)	6.4 (0.97)

[a] Values are means (and standard deviations). TWD, texting-while-driving group; Non-TWD, non-texting-while-driving group.

frequently text while driving. Therefore, the purpose of the present study was to compare the rate of delay discounting of drivers who frequently text while driving with that of drivers who infrequently text while driving. It was hypothesized that college students who frequently text while driving will demonstrate greater rates of delay discounting than a control group of students matched according to gender, age, years of higher (tertiary) education, and years driving.

2. Materials and methods

2.1. Participants

One hundred forty-seven undergraduate students enrolled in introductory psychology courses at a state university in the Northeastern United States participated. They were offered course credit for completing a delay-discounting task (described below), a demographic survey, and a part of the survey developed by Atchley et al. (2011) that assessed various patterns of texting while driving as well as its perceived dangers. Students who reported that they had no history of driving on the demographic survey ($N = 27$) were excluded from the study and their data were not analyzed. In delay-discounting research, it is fairly common to find nonsystematic patterns of responding due to a number of idiosyncratic variables, such as carelessness or random responding. Consistent with previous studies (e.g., Rasmussen et al., 2010), the decision to exclude nonsystematic responders was based on the theoretically neutral algorithm developed by Johnson and Bickel (2008). We excluded individuals' data from analysis if (a) any indifference point was greater than the preceding indifference point by more than 20% or (b) the last indifference point was not smaller than the first indifference point by at least 10%. Using this algorithm, students who exhibited nonsystematic response patterns on the delay-discounting task ($N = 28$) were excluded. The remaining sample was composed of 40 male and 52 female students. Their mean age, years of education, and years driving were 19.6 ($SD = 4.5$; ranging from 18 to 57), 1.6 ($SD = 1.0$; from 1 to 6), and 3.3 ($SD = 4.8$; from 1 to 45), respectively.

Based on the mean score of 5.0 or higher on the frequency scale of reading, replying, and initiating a text message developed by Atchley et al. (2011), 19 students were assigned to the texting while driving (TWD) group. For comparison, a control group of students, who do not frequently text while driving, were selected from among 42 students with the mean score of 3.0 or lower on the frequency scale. Among this group, 19 students, who most closely matched the TWD students on gender, years of higher education, and years of driving experience, were assigned to the Non-TWD group. Table 1 summarizes the demographic characteristics of the two groups. A dependent-samples *t* test showed that there was a significant difference in the frequency of texting while driving between the two groups, $t(18) = 18.41$, $p < .001$, and that there were no significant differences between the groups on age, $t(18) = 0.30$, $p = .76$; years of higher education, $t(18) = -0.20$, $p = .84$; years driving, $t(18) = 0.22$, $p = .83$; and perceived danger of texting while driving, $t(18) = -1.34$, $p = .20$.

2.2. Procedure

A session was conducted in a large class room. Each participant received a packet that contained the delay-discounting task, the demographic survey, and a part of the survey on texting while driving developed by Atchley et al. (2011). On the first page of the packet, students read the following instructions (adapted from Saville et al., 2010):

> On the next few pages, you will be asked to make a series of choices between two hypothetical amounts of money. One amount could be obtained immediately; the other amount would be available after a certain period of time. For example, you might be asked to choose between:
> $800 now or $1,000 in 2 weeks
> There are no right or wrong answers. We are simply interested in the option you prefer, so please make your choices as honestly and accurately as possible. Do not rush through this survey, randomly choose your answers, or flip back and forth between sheets.

The delay-discounting task was adapted from Rachlin et al. (1991). Participants were required to make a series of choices between a smaller amount of hypothetical money available immediately and a larger amount of hypothetical money available after some delay. On each page of the task, participants made 30 choices. The smaller immediate rewards were listed in ascending order in the left column on each page. They ranged from $1 to $1000 (1, 5, 10, 20, 40, 60, 80, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 920, 940, 960, 980, 990, and 1000). The larger delayed reward was presented in the right column on each page, and it was always $1000 available after a fixed delay. There were seven delay values—1 week, 2 weeks, 1 month, 6 months, 1 year, 3 years, and 10 years—each presented on a separate page. Participants indicated the alternative they preferred with a checkmark.

After the delay-discounting task, participants completed the demographic survey (age, gender, years of education, and years driving) and the survey on texting while driving. Students rated, on a 7-point Likert scale, their frequency and perceived danger of reading, replying, and initiating a text message while driving. The questions on frequency used the anchors 1: never and 7: always, and the questions on perceived danger used the anchors 1: not at all and 7: extremely.

3. Results

Fig. 1 shows the median subjective values of the delayed rewards for the TWD and Non-TWD groups as a function of the delay. The subjective values are based on indifference points at which the larger, delayed reward is subjectively equivalent to the smaller, immediate reward calculated using the method described by Rachlin et al. (1991). The curves represent Eq. (1) fitted to the group medians using least squares nonlinear regression performed with Solver function in Microsoft Excel 2010. For both groups, the subjective value of the rewards was discounted hyperbolically as a function of delay, and Eq. (1) described the data well ($R^2 = .985$ for the TWD group and $R^2 = .905$ for the Non-TWD group). Visual analysis of Fig. 1 reveals that the TWD students discounted the delayed rewards at a greater rate than the Non-TWD students. That is, the

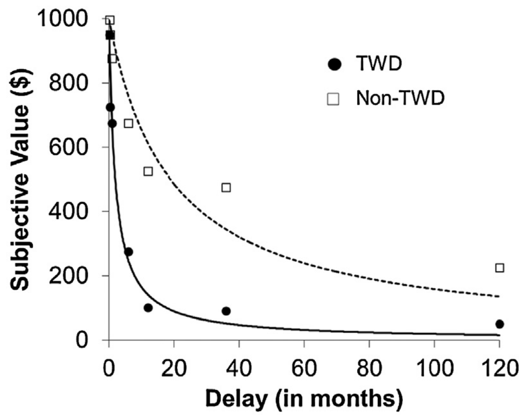

Fig. 1. Subjective value of hypothetical monetary rewards as a function of delay to the reward for students who frequently text while driving (TWD, closed circles) and students who infrequently text while driving (Non-TWD, open squares). Group medians are plotted with the hyperbolic discounting function from Eq. (1).

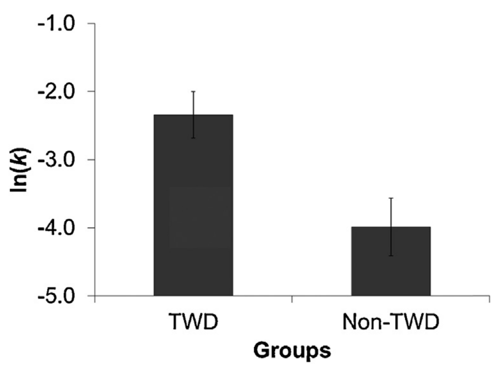

Fig. 2. Mean natural log-transformed k values for TWD and Non-TWD groups. The error bars represent the standard error of the mean.

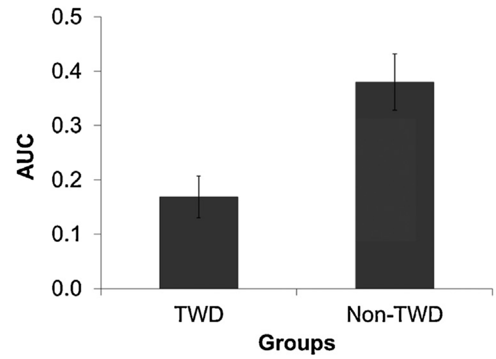

Fig. 3. Mean area under the curve (AUC) for TWD and Non-TWD groups. The error bars represent the standard error of the mean.

devaluation of future rewards was greater for the TWD group than for the Non-TWD group.

To further analyze the difference between the TWD and Non-TWD students, two statistical analyses were conducted. First, Eq. (1) was fitted to the indifference points for each participant and the parameter k, which represents the rate of discounting, was derived. Recall that a higher k value indicates great discounting and thus greater impulsivity. Because k values typically result in skewed distributions (Myerson and Green, 1995; Rachlin et al., 1991), it is common to normalize the distribution through transformation of the data. Consistent with previous studies (e.g., Bickel et al., 2014c), natural log transformed data were used for analysis. Fig. 2 shows the mean ln(k) values for the TWD and Non-TWD groups. A dependent-samples t test showed that there was a significant difference between groups, $t(18) = 2.64$, $p = .02$. Second, the area under the discounting curve (AUC) was calculated for each participant based on the method described by Myerson et al. (2001). AUC is a descriptive, non-theoretical measure of discounting that represents the actual area created by the indifference points at each delay, whose values tend to be normally distributed. Fig. 3 shows the mean AUC for the TWD and Non-TWD groups. A dependent-samples t test showed that there was a significant difference between groups, $t(18) = -3.13$, $p < .01$. Taken together, these two statistical analyses support the visual inspection of Fig. 1, demonstrating that the TWD group discounted delayed rewards at a significantly greater rate than the Non-TWD group.

Table 2 shows Pearson correlation coefficients of the demographic characteristics and delay-discounting measures. Because the assignment of students to the TWD and Non-TWD groups with the frequency score of 5.0 or higher and 3.0 or lower, respectively, was somewhat arbitrary, correlational analyses between the frequency of texting while driving and the delay discounting rate were conducted with the total sample of participants ($N = 92$). As shown on the table, both the ln(k) value and the AUC were significantly correlated with TWD frequency. Thus, there were direct and inverse relations, respectively, between the ln(k) value and TWD frequency and between the AUC and TWD frequency. Other noteworthy findings include: (a) no significant correlation between the frequency of texting while driving and the perceived danger of texting, and (b) no significant correlations between the perceived danger of texting while driving and the delay-discounting measures ln(k) and AUC.

Finally, correlational analyses between the frequency of texting while driving and the delay discounting rate were conducted with all participants with driving experience ($N = 120$), excluding 27 participants with no history of driving but including 28 participants who exhibited nonsystematic response patterns on the delay-discounting task. This analysis was conducted as the most conservative measure with non-systematic responders included. The results show that the relations between texting while driving and delay discounting described above still hold when the nonsystematic data are included. Both the ln(k) value and the AUC were significantly correlated with the TWD frequency, $r(118) = .18$, $p < .05$ for the ln(k) value and $r(118) = -.30$, $p < .001$ for the AUC.

4. Discussions

The present study investigated the utility of a behavioral economic approach for investigating the underlying processes associated with texting while driving. The rate of delay discounting, a behavioral measure of impulsivity, was compared between a group of college students who frequently text while driving and a matched control group. A hyperbolic delay-discounting function provided a good fit of indifference points for both groups of students. Multiple measures of delay discounting indicate that students who frequently text while driving discounted delayed rewards at a greater rate than students who infrequently text while driving. These results support the conclusion that texting while driving is fundamentally an impulsive choice made by drivers while they are driving.

The present results are consistent with previous studies that examined the relation between impulsivity-related personality constructs and texting while driving. As mentioned previously, Pearson et al. (2013) found that college students who frequently text while driving scored higher on the impulsivity-like personality trait of *negative urgency*. Similarly, Feldman et al. (2011) found that college students who text while driving frequently are lower in *mindfulness*, which is linked to difficulties with emotion regulation

Table 2
Pearson correlation coefficients of demographic characteristics and delay-discounting measures with the total sample of participants.

	1	2	3	4	5	6	7	8
1. Age in years	–							
2. Gender (0: female, 1: male)	.18	–						
3. Years of higher education	.19	.02	–					
4. Years driving	.96***	.16	.14	–				
5. Frequency of TWD	−.08	.14	−.08	−.06	–			
6. Perceived danger of TWD	.01	−.36***	−.18	.01	−.18	–		
7. ln(*k*)	−.20	−.01	−.09	−.13	.34***	.05	–	
8. AUC	.22*	.02	.17	.15	−.38***	−.04	−.92***	–

Note. TWD, texting while driving; AUC, area under the curve.
* $p < .05$.
*** $p < .001$.

(Feldman et al., 2007). The present study, showing that students who frequently text while driving are more impulsive as measured by delay discounting, joins these studies and further supports the notion that measures of traits associated with impulsivity are useful for predicting individuals at risk for texting while driving. Nevertheless, the present study uniquely contributes to the literature by demonstrating the utility of assessing impulsivity with a behavior-based measure, which can supplement self-reported measures by shedding light on the underlying behavioral and cognitive processes—namely the subjective devaluation of delayed rewards.

One interesting aspect of the present results is the lack of a relation between impulsivity, as measured by delay discounting, and perceived risk of texting while driving, despite the fact that the delay discounting measure does correlate with the frequency of texting while driving. A discrepancy between the perceived risk and the engagement of the behavior of texting while driving is consistent with the results of some studies (e.g., Atchley et al., 2011; Ginsburg et al., 2008). But the finding is inconsistent with other studies (e.g., Ryb et al., 2006) in which low risk perception and high impulsivity were significant risk factors for risky behaviors, such as infrequent seat-belt use and drinking and driving. Conducting more research to reconcile these discrepant findings would further our understanding of the relation between impulsivity and perceived risk.

In accord with delay-discounting studies conducted with different populations, species, and types of rewards (Bickel et al., 1999; Johnson and Bickel, 2002; Kirby, 1997; Mazur and Biondi, 2009), choice patterns for hypothetical monetary rewards in the present study were well described by the hyperbolic delay-discounting function. The function posits that the rate of discounting decreases as delay increases. This disproportional change in subjective value of rewards over time may help to explain why many drivers text while driving despite their awareness of the risks. From a behavioral economic perspective, this *self-control* failure is best understood in term of preference reversal, which refers to a shift in preference from a larger-later reward to a smaller-sooner reward as the receipt of the reward approaches (e.g., Green et al., 1981). This preference reversal can occur if (a) delayed rewards are discounted in accordance with the hyperbolic delay-discounting function and (b) the rate of discounting is sufficiently high.

To illustrate how texting involves a preference reversal, consider the hypothetical scenarios involving a smaller-sooner reward (e.g., short text messages while driving) and a larger-later reward (e.g., a longer conversation sometime later when not driving) for two individuals shown in Fig. 4. Note that Fig. 4 is similar to Fig. 1 in that both show hyperbolic changes in the subjective value of rewards as a function of time. Individual 2 (bottom panel), with greater rates of delay-discounting, is more impulsive than Individual 1 (top panel) as depicted by the steeper discounting function associated with the larger-later reward. In both panels, Time A depicts the moment of opportunity to receive a smaller-sooner reward (white bar), and Time B depicts the moment of opportunity to receive a larger-later reward (black bar). Hypothetical delay-discounting functions are shown for the smaller-sooner reward (dashed line) and the larger-later reward (solid line). At Time C, opportunities to receive either small or large reward is temporally remote, and both individuals would place a greater value on the larger-later reward over the smaller-sooner reward. As time approaches D, the opportunity for

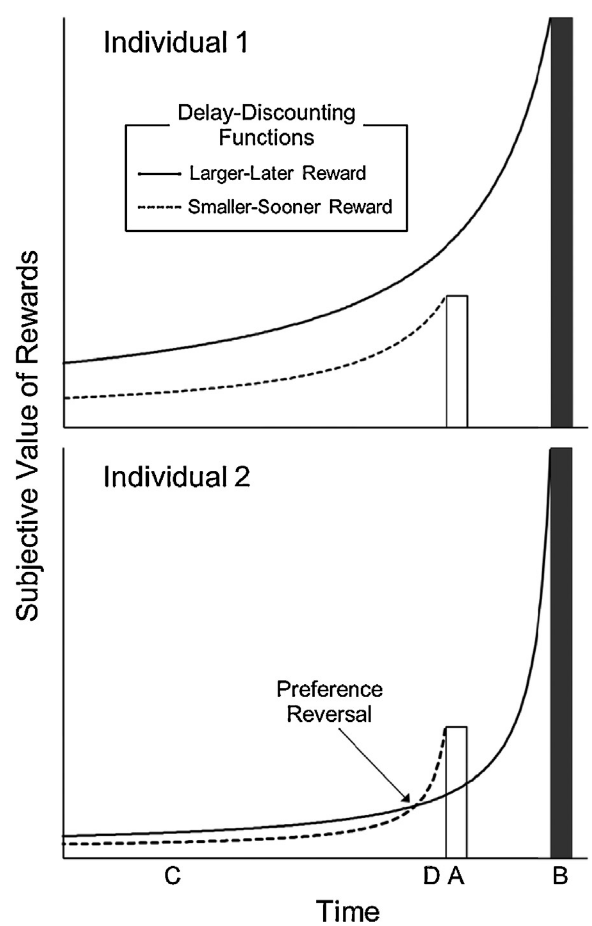

Fig. 4. Hypothetical scenarios for Individuals 1 and 2 with different rates of delay discounting. In both panels, Time A depicts the time associated with an opportunity to receive a smaller-sooner reward (white bar), and Time B depicts the time associated with an opportunity to receive a larger-later reward (black bar). Hypothetical delay-discounting functions are shown for the smaller-sooner reward (dashed line) and the larger-later reward (solid line). At Time C, opportunities to receive either reward is temporally remote, and both individuals would place a greater value on the larger-later reward. At Time D, Individual 1 still places a greater value on the larger-later reward, whereas Individual 2 after a preference reversal places a greater value on the smaller-sooner reward.

the smaller-sooner reward becomes more eminent. At Time D, Individual 1 still places a greater value on the larger-later reward than the smaller-sooner reward, whereas Individual 2 after a preference reversal places a greater value on the smaller-sooner reward than the larger-later reward. This preference reversal is essential for understanding the self-control failure in general, and the good fit of the data to hyperbolic-discounting functions suggests that preference reversal is an important process involved in texting while driving.

Finally, the results of the present study are consistent with those of previous studies showing a relation between delay discounting and other impulsivity-related behaviors, such as substance use and gambling, in both clinical (e.g., Bickel et al., 1999; Dixon et al., 2003) and nonclinical (e.g., Kollins, 2003; Stea et al., 2011) populations. Therefore, the present study extends the current literature to texting while driving. Recently, it has been suggested that delay discounting plays an etiological role in substance use (see Bickel et al., 2014a, for review). For example, several longitudinal studies found that delay discounting predicts development of addictive behavior (e.g., Audrain-McGovern et al., 2009). In addition, studies have demonstrated that increased delay discounting serves as a negative prognostic factor for treatment success in substance-use disorders (see Loree et al., 2014, for review). The strong link between texting while driving and discounting may suggest that delay discounting also plays an etiological role in texting while driving.

A link between texting while driving and impulsivity further suggests that intervention approaches, which are effective for other impulsivity-related behaviors (e.g., commitment and contract interventions, contingency management, and mindfulness-based interventions), may be effective for texting while driving. These interventions may be more effective following an assessment of delay discounting to identify individuals who are at most risk of texting while driving (cf. see Bickel et al., 2014b, for the utility of a delay discounting measure as a predictor of success in substance abuse treatment).

Consider, for example, a deposit contract intervention in which participants supply a relatively large sum of money and agree to forfeit it if they fail to achieve the predetermined goal. This intervention has been shown to be effective in controlling behaviors similar to texting while driving that require self-control (e.g., Dallery et al., 2008; Volpp et al., 2008). From a behavioral economic perspective, the intervention is considered a precommitment strategy (Rachlin and Green, 1972) that allows participants to commit to a larger-later reward while its value is greater than that of a smaller-sooner reward (cf. Time C on Fig. 4). Depositing money is not the only way to make a precommitment choice, however. For example, AT&T DriveMode® is a free app that silences an alert of incoming text messages and automatically replies to the messages (AT&T, 2013). Installing the app and turning it on before driving is also a precommitment choice that may decrease the chance of replying to a text while driving. Another incentive-based intervention, contingency management (e.g., Higgins et al., 2008), is a program in which a reinforcer is delivered contingent on desirable behavioral change (e.g., participants receive a voucher exchangeable for goods or service by proving a drug-free urine sample). This intervention increases costs (i.e., loss of reinforcement) associated with an undesirable behavior, which results in increased frequency of the desirable behavior that produces a larger-later reward (Bickel et al., 2014a). Finally, mindfulness-based interventions are shown to be effective for treating various impulsivity-related behaviors (e.g., Chiesa and Serretti, 2014; Lisle et al., 2011), particularly for individuals who engage in such behaviors to alleviate emotional, physical, or cognitive discomfort (Bowen and Marlatt, 2009). Given the findings that individuals who are low in mindfulness are more likely to text while driving (Feldman et al., 2011) and that mindfulness-based interventions actually decreased discounting of delayed rewards (Hendrickson and Rasmussen, 2013; Morrison et al., 2014), it is possible that mindfulness-based interventions are an effective solution for texting while driving (see also Ashe et al., 2015, for review on delay discounting and mindfulness-based interventions).

4.1. Limitations

Several limitations of the present study are noteworthy. First, unlike *naturalistic* driving studies in which observational data are taken with on-board cameras that objectively record actual behaviors in real time (e.g., Klauer et al., 2014), the present study relied on participants' self-report of the frequency of texting while driving. It is possible that the accuracy of the self-report measure was influenced by the bias in participants' memory of texting while driving (Struckman-Johnson et al., 2015) or social desirability bias (Nederhof, 1985). The presence of such biases could lead to a random or inaccurate categorization of two groups of students (in the case of the memory bias) or the erroneous assignment of students, who frequently text while driving, to the Non-TWD group (in case of social desirability bias). In either case, the bias makes it more difficult to reject the null hypothesis that two groups of students do not differ in the rate of delay discounting. Given the robust differences in delay discounting between the groups, the self-report assessment of texting frequency in the present study does not cause a serious challenge to the conclusions. Nevertheless, naturalistic methods that more objectively assess the frequency and duration of texting while driving would be a more valid approach for future studies.

Second, the sample exclusively consisted of college students, and thus the results cannot be generalized beyond this population. The study would have been improved by using a more diverse sample. Previous research has shown that the frequency of texting while driving differs across age groups. According to Braitman and McCartt (2010), for example, the percentage of drivers who reported some texting while driving was highest among drivers 18–24 years old and lowest among drivers 60 and older. It is not known whether older and more experienced drivers who frequently text while driving also discount delayed rewards at a greater rate those who infrequently text while driving.

Third, all choices were made between hypothetical rewards. In general, choice patterns based on hypothetical rewards or outcomes can be different from those based on real outcomes (i.e., those that participants actually experience). For example, studies of risk-taking have shown that in general individuals tend to take more risks with hypothetical outcomes than with real outcomes (e.g., Irwin et al., 1992). On the other hand, with respect to delay discounting of monetary rewards in particular, there is empirical evidence demonstrating that hypothetical and real monetary rewards produce similar results (e.g., Johnson and Bickel, 2002; Lagorio and Madden, 2005; Madden et al., 2003, 2004). Thus, the use of hypothetical monetary rewards can be justified, at least in the context of the present study.

Forth, the present study relied on monetary rewards to assess delay discounting. Drivers typically do not choose to text for monetary rewards, and thus the results must be viewed with caution. Nevertheless, a delay-discounting task using hypothetical monetary rewards is still valid for assessing individuals' general choice bias favoring immediate rewards in lieu of larger and delayed rewards (Yi et al., 2010), and such a bias is indeed the focus of the present study. Furthermore, the generality of the choice bias, based on hypothetical choice procedures, has been established across a variety of commodities including monetary and informational reward (e.g., Atchley and Warden, 2012), various drugs (e.g., Bickel et al., 1999; Madden et al., 1997), social interactions (e.g., Charlton et al., 2012), health outcomes (e.g., Odum et al., 2002), sexual outcomes (e.g., Lawyer et al., 2010), and food (e.g., Rasmussen et al., 2010). Nevertheless, the present study would have been improved by assessing the discounting of other rewards more functionally related to texting while driving (e.g., desire for social interaction or communication).

Finally, as a first step toward a greater understanding of the behavioral and cognitive processes underlying texting while driving, the present study simplified the behavior of texting while driving as a trade-off between a smaller-sooner reward and a larger-later reward. Although there is a robust difference in delay discounting between students who frequently text while driving and those who do not, the impulsive decision to text while driving is a complex phenomenon, and there are other factors that influence decision making. For example, texting while driving can also involve a trade-off between obtaining a smaller-sooner reward (i.e., text message) and avoiding a larger-later (or probable) aversive outcome (i.e., motor vehicle accident). Furthermore, an impulsive choice to text while driving is a behavioral phenomenon subject to numerous contextual and environmental variables, such as the perceived importance of the text or its sender (cf. Atchley and Warden, 2012) and road or weather conditions. Experimental methods that take these factors into account are important and fruitful directions for future research.

4.2. Conclusion and future research

The goal of the present study was to examine the utility of a behavioral economic analysis of texting while driving by assessing delay discounting. Consistent with our hypothesis, college students, who frequently text while driving, demonstrated greater rates of delay discounting than a group of matched-control students. The present study contributes to the literature on texting while driving by demonstrating that texting may be related to individual differences in impulsivity as measured by the discounting of delayed hypothetical monetary rewards. Linking the process of delay discounting to texting while driving also provides a conceptual framework that may lead to a better understanding of the behavioral and cognitive processes that underlie drivers' decisions to text while driving.

An important direction for future research is to further investigate the variables that influence the drivers' decisions to text while driving. Toward this end, an important next step is to develop choice scenarios that more closely simulate the decisions that drivers make when texting while driving. Instead of using only hypothetical monetary rewards, choice scenarios should incorporate the subjective value of other possible outcomes (i.e., opportunities for social interaction, communication of important messages, etc.) to better account for the range of factors and conditions that contribute to texting while driving (cf. Atchley and Warden, 2012; Charlton et al., 2012). When refined and validated, the procedures can also be used to evaluate the efficacy of various behavior- or technology-based interventions—interventions that exist currently or as hypothetical or future concepts. These procedures would serve as powerful research tools, not only for revealing important variables that influence impulsive decision-making associated with texting while driving, but also for evaluating promising solutions that prevent or decrease texting while driving.

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