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# Texting while driving, executive function, and impulsivity in college students

**Yusuke Hayashi**[a,*], **Esteban A. Rivera**[a], **James G. Modico**[a], **Anne M. Foreman**[b], and **Oliver Wirth**[b]

[a]Pennsylvania State University, Hazleton, 76 University Drive, Hazleton, PA 18202, USA

[b]National Institute for Occupational Safety and Health, 1095 Willowdale Rd, Morgantown, WV26505, USA

## Abstract

The purpose of the present study was to investigate the cognitive processes underlying texting while driving. A sample of 120 college students completed a survey to assess how frequently they send and read a text message while driving. Based on this information, students were assigned to one of two groups: 20 students who frequently text while driving and 20 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 differed in self-reported measures of executive function and impulsivity. The groups were also compared on a behavioral measure of impulsivity: the extent to which they discounted hypothetical monetary rewards as a function of the delay. For this measure, the students made repeated choices between smaller monetary rewards available immediately and larger rewards available after delays ranging from 1 week to 6 months. The results show that the group of students who frequently text while driving showed (a) significantly lower levels of executive function and (b) higher levels of self-reported impulsivity, although the groups did not differ significantly on the behavioral measure of impulsivity. These results support a general conclusion that drivers with lower levels of executive function and higher levels of impulsivity are more likely to text while driving.

### Keywords

Texting while driving; Executive function; Impulsivity; Delay discounting; Decision making; College students

## 1. Introduction

In 2014 in the United States, 3179 people were killed and an estimated additional 431,000 people were injured in motor vehicle crashes caused by distracted driving (National Highway Traffic Safety Administration [NHTSA], 2016). The NHTSA (2014) defined distracted driving as driving with drivers' attention away from the driving task to focus on another activity. Distracted driving can be visual or sensory (e.g., looking away from the

[*]Corresponding author at: Division of Social Sciences and Education, Pennsylvania State University, Hazleton, 76 University Drive, Hazleton, PA 18202, USA. yuh26@psu.edu (Y. Hayashi).

roadway), manual (e.g., taking a hand off the steering wheel and manipulating a device or object), or cognitive (e.g., thinking about something other than driving), all of which increase the risk of a motor vehicle crash (NHTSA, 2014). It is estimated that, in 2010, the total economic costs associated with motor vehicle crashes due to distraction in the United States were at least $40 billion (Blincoe et al., 2015).

Texting while driving involves all three types of distractions discussed (Sherin et al., 2014). The National Safety Council (2015) estimated that, in 2013, 6–16% of motor vehicle crashes, or 341,000 to 910,000 crashes, in the United States are likely attributable to text messaging. Despite its danger, 31.2% of drivers aged 18–64 years in the United States reported that they had read or sent text messages while driving in the past 30 days, and in seven European counties surveyed, the percentages ranged from 15.1% in Spain to 31.3% in Portugal (Centers for Disease Control and Prevention, 2013). Texting while driving is particularly pervasive among young drivers. In the United States, for example, 74–92% of college students surveyed reported they engage in texting while driving (Atchley et al., 2011; Cook and Jones, 2011; Harrison, 2011).

To predict who is most likely to text while driving, previous research has identified various psychological factors associated with this risky behavior. These factors can be grouped into four broad categories: (a) attitude, tendency, and intention toward mobile phone use, (b) risk perception and risk tendency, (c) impulsivity and lack of self-control, and (d) emotional regulation. Each of these will be discussed below.

Previous research has found a positive correlation between the self-reported frequency of texting while driving and several attitudes, tendency, and intention toward mobile phone use. These include cell phone dependency (Struckman-Johnson et al., 2015), perceived need for a mobile phone while driving (Musicant et al.,2015), tendency to automatically engage in texting (Bayer and Campbell, 2012; Panek et al., 2015), and intention to text while driving (based on the theory of planned behavior; Benson et al., 2015; Nemme and White, 2010; Prat et al., 2015). As expected, those who are dependent on a mobile phone and those who have high need or intention to text while driving tend to engage in texting while driving more frequently.

The second category is individuals’ perceived risk of texting while driving and risk tendency. In general, there is a negative correlation between risk perception and tendency and frequency of texting while driving, but the relation is moderated by gender. Struckman-Johnson et al. (2015) investigated gender differences in psychological predictors of texting while driving and found that, for male college students, higher perceived texting distractibility (how distracted they are from driving when they text) was significantly associated with a lower frequency of texting while driving, whereas, for female students, higher risky behavior tendencies were significantly associated with a lower frequency of texting while driving.

The third category is the personality trait of impulsivity. Here, impulsivity refers to “a tendency to act on a whim and, in so doing, disregards a more rational long-term strategy for success” (Madden & Johnson, 2010, p. 11). It is synonymous with lack of self-control.

Several studies have found a significant correlation between texting while driving and self-reported measures of impulsivity and self-control (Lantz and Loeb, 2013; Panek et al., 2015; Quisenberry, 2015; Struckman-Johnson et al., 2015; see also Biçaksiz and Özkan, 2016, for review on impulsivity and other driving behaviors). Using a *delay discounting* paradigm, Hayashi et al. (2015) compared the extent to which students, who frequently or infrequently text while driving, discounted the subjective value of hypothetical delay monetary rewards. They found that students who frequently texted while driving were more impulsive as measured by the delay discounting task. In a subsequent study by Hayashi et al. (2016) using a hypothetical texting while driving scenario, impulsivity was measured by delay discounting of both monetary and social rewards (i.e., opportunities to reply to a text message). Consistent with the previous study, students who frequently texted while driving were more impulsive, only with the social reward.

Finally, the fourth category is the ability to regulate negative emotions. Pearson et al. (2013) found that the personality trait of negative urgency, which refers to "the tendency to act impulsively when experiencing negative affect" (p. 142), was a significant predictor of frequency of texting while driving in college students: the higher the negative urgency, the greater the frequency of texting while driving. They also found that the trait of positive urgency, which refers to "behaving impulsively when experiencing positive affect" (p. 142), was a significant predictor of some driving outcomes (e.g., traffic citation) but not of texting while driving. Similarly, Feldman et al. (2011) and Panek et al. (2015) investigated a relation between the frequency of texting while driving and individual differences in the personality trait of *mindfulness.* Mindfulness refers to the awareness that emerges through paying attention to particular experiences in the present moment (Kabat-Zinn, 2003) and is associated with abilities to regulate emotions (Feldman et al., 2007). Studies show that students who are low in mindfulness are more likely to text while driving (Feldman et al., 2011; Panek et al., 2015).

Although previous studies have made progress in identifying who is more likely to text while driving, the behavioral, cognitive and neurological processes underlying drivers' decision to read and send text messages while driving are not well understood. For example, one hallmark of texting while driving is that drivers engage in texting while driving despite awareness of its negative consequences (Atchley et al., 2011). The decision-making process underlying this impulsive behavior warrants further investigation (cf. Hayashi et al., 2015). As an initial step, the identification of cognitive and neurological factors that are relevant to the underlying processes of texting while driving is of great importance. One potential candidate is *executive function.*

Executive function is defined as "cognitive abilities for adaptive functioning, allowing for behavior that is more goal-oriented, flexible, and autonomous" (Spinella, 2005). These abilities are said to be "executive" because they are essential for the integration and processing of the information obtained from a wide range of internal and external experiences (Christ et al., 2011). Although researchers have yet to identify a definitive list of components of executive function (Schmeichel and Tang, 2015), it is presumed to encompass cognitive processes, such as inhibition, planning, switching, self-monitoring, self-regulation, attention, and working memory, that are carried out by prefrontal areas of the frontal lobe (Goldstein et al., 2014).

Previous research has shown that executive function is inversely associated with addictive disorders, such as substance abuse (Goldstein and Volkow, 2011) and pathological gambling (e.g., Reid et al., 2012) as well as various impulsivity-related problems, such as obesity (e.g., Smith et al., 2011), internet addiction (e.g., Zhou et al., 2014), texting dependency (Ferraro et al., 2012), and hyper-sexual behavior (e.g., Reid et al., 2010). If texting while driving shares some key features with these addictive, risky, and impulsive behaviors, executive function should also be an important factor in understanding the cognitive mechanism that underlies texting while driving.

With respect to driving behavior, previous research has demonstrated a strong link between executive function and driving behaviors other than texting while driving. For example, lower levels of executive function were associated with poorer simulated and on-road driving performance (Adrian et al., 2011; Guinosso et al., 2016; Mäntylä et al., 2009). Similarly, a group of older drivers who had three or more motor vehicle crashes in the last 5 years showed lower levels of executive function than the control group with no history of crashes (Daigneault et al., 2002). In addition, drivers who had been caught for speeding by the police and drivers who lost points due to traffic violation showed lower levels of executive function than non-offenders (Leoón-Domínguez et al., 2016; O'Brien and Gormley, 2013). Interestingly, however, higher levels of executive function, as measured by a working memory task, were associated with higher levels of self-reported risky driving in adolescent drivers (Starkey and Isler, 2016). Starkey and Isler reasoned that higher levels of executive function, such as better attention or memory capacity, may actually increase drivers' risk taking because these individuals may feel confident about dealing with unplanned or unforeseen consequences (Patrick et al., 2008).

Taken together, previous research suggests that executive function should be an important factor in understanding the cognitive and neurological mechanism that underlines texting while driving. Despite its potential significance, a relation between executive function and texting while driving has received little empirical attention. One notable exception is Pope et al. (2017), in which lower levels of executive function were related to a higher frequency of distracted driving in young, middle age and older drivers. It is important to note, however, that Pope et al. (2017) averaged data from multiple behaviors (e.g., drinking, eating, talking, using a GPS, and texting) and employed a general index of distracted driving as a dependent variable. Although all of these behaviors are distracting, the cognitive mechanism underlying these behaviors may differ. In addition, the frequency of each behavior may also differ. For example, those who frequently engage in voice calls while driving may not text while driving. Therefore, it is still important to investigate whether drivers who engage in texting while driving show different levels of executive function.

The purpose of the present study was to compare two populations of drivers—those who frequently and infrequently text while driving—on levels of executive function in a cross-sectional manner. As mentioned previously, a study of executive function with respect to texting while driving is of significance because it may shed some light on the cognitive and neurological processes involved. Better understanding of such processes in a population of drivers who frequently text while driving is important because it can lead to the development of an effective strategy to decrease texting while driving. It was hypothesized that a group of college students who frequently text while driving would demonstrate a lower level of executive function than a control group of students matched according to gender, age, years of higher education, and years driving.

As a first step in understanding the role of executive function and impulsivity in texting while driving, the present study compared students who frequently and infrequently text while driving on measures of self-reported impulsivity and a behavioral index of impulsivity that assessed their valuation of delay monetary rewards. This comparison also serves as a test for the external validity of the previous studies that showed a relation between the level of impulsivity and frequency of texting while driving (e.g., Hayashi et al., 2015; Struckman-Johnson et al., 2015). It was hypothesized that a group of students who frequently text while driving would demonstrate a higher level of impulsivity on both self-reported and behavioral measures than a control group of students who do not frequently text while driving.

## 2. Material and methods

### 2.1. Participants

One hundred and twenty undergraduate students enrolled in an introductory psychology course at a university in the north-eastern United States participated. They were offered course credit for participation. Students with no history of driving (*N*=20) were excluded. The remaining sample consisted of 45 males and 55 females. Mean age, years of higher education, and years driving were 19.3 (*SD* = 4.4; ranging from 18 to 60), 1.4. (*SD* =1.1; from 0.5 to 8), and 2.9. (*SD* = 4.1; from 0.5 to 40), respectively. The Institutional Review Board at the Pennsylvania State University approved the study protocol, and all participants provided written informed consent.

### 2.2. Procedure

Sessions were conducted in a large classroom. The participants completed a demographic questionnaire and three questionnaires on executive functioning, self-reported impulsivity, and behavioral impulsivity.

**2.2.1. Demographic questionnaire—**In addition to the basic demographic information such as age, gender, years of higher education, and years driving, the demographic questionnaire included two sets of questions adapted by Atchley et al. (2011) that measured frequency and perceived danger of reading, replying, and initiating a text message while driving. These questions employed a 7-point Likert scale ranging from 1 (*never*) to 7 (*always*) for Frequency (e.g., "How often do (did) you read a text while driving?") and 1 (*not at all*) to 7 (*extremely*) for Perceived Danger (e.g., "In general, how dangerous is it to reply to a text while driving?").

For comparison, the participants were divided into two groups, a texting while driving (TWD) group and a non-TWD group. Group assignment was determined by scores on Atchley et al.'s (2011) texting frequency survey. Twenty participants with a mean score of

5.0 or higher on the frequency scale of reading, replying, and initiating were assigned to the TWD group. For comparison, 53 participants with the mean frequency score of 3.0 or lower were identified. Among these participants, 20 participants who most closely matched the TWD group on gender, years of higher education, and years of driving experience were selected and assigned to the Non-TWD group. If more than one participant had the same demographic characteristics, and these participants were being matched to a participant in the TWD group, the one with a smaller participant number was chosen (cf. the participant numbers were assigned randomly). Table 1 shows the demographic characteristics and frequency and perceived danger of texting while driving of the two groups.

**2.2.2. Executive Function Index—**The Executive Function Index (EFI; Spinella, 2005) is a self-reported measure of executive function. Unlike other self-reported measures of executive function developed for clinical purposes (e.g., the Frontal Systems Behavior Scale), the EFI was developed with a non-clinical healthy adult population. The EFI consists of 27 questions that are categorized into five subscales (Motivational Drive, Organization, Strategic Planning, Impulse Control, and Empathy). Each question consists of a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*very much*). The scores from negatively worded items are reversed, and higher scores on the subscales and the total score represent higher levels of executive functioning. The EFI demonstrates good internal consistency (Cronbach's alpha = 0.82), and the items associated with prefrontal system dysfunction demonstrate good content validity in clinical and neuroimaging studies (Spinella, 2005).

**2.2.3. Barratt Impulsiveness Scale—**The Barratt Impulsiveness Scale (BIS-11; Patton et al., 1995) is a self-reported measure of the dispositional trait of impulsivity. The BIS-11 consists of 30 questions that are categorized into three second-order subscales (Attentional Impulsivity, Motor Impulsivity, and Non-Planning). Each question uses a 4-point Likert scale ranging from 1 (*rarely/never*) to 4 (*almost always/always*). As with the EFI, the scores on negatively worded items are reversed, and higher scores on the subscales and the total score represent higher levels of impulsivity. The BIS demonstrates good internal consistency (Cronbach's alpha = 0.82; Stanford et al., 2009). Validity of the BIS-11 has been shown by several studies using clinical populations (e.g., Patton et al., 1995), neuroimaging (e.g., Hoptman et al., 2002), and neuropsychological measures of prefrontal dysfunction (e.g., Spinella, 2004).

**2.2.4. Monetary Choice Questionnaire—**The Monetary Choice Questionnaire (MCQ; Kirby et al., 1999) is a behavioral measure of impulsivity that consists of a fixed set of 27 choices between smaller, immediate rewards, and larger, delayed monetary rewards. For example, participants were asked, "Would you prefer (a) $55 today or (b) $75 in 61 days?" They were instructed to indicate which alternative they would prefer by circling it. The 27 questions were grouped into three categories based on the size of the delayed rewards: small ($25-$35), medium ($50-$60), and large ($75-$85). The delays ranged from 7 to 186 days. Based on the patterns of choices, a discounting rate k, a parameter that reflects the degree to which the subjective value of delayed reward is discounted as a function of the time to its receipt, is estimated (see Kirby et al., 1999; for scoring details). The $k$ values can range from 0.00016 to 0.25, and higher $k$ values indicate greater impulsivity. The MCQ demonstrated good 1-year rest-retest stability (0.71; Kirby, 2009) as well as good construct validity with clinical populations (e.g., Kirby and Petry, 2004; Kirby et al., 1999).

### 2.3. Data analyses

Statistical analyses were performed using SigmaPlot 12 (Systat Software Inc., SanJose, CA). Matched-sample *t*-tests (Howell, 2002) were used to compare the difference between the TWD and the Non-TWD groups on levels of executive function and impulsivity. The *k* values from the MCQ were natural-log transformed because *k* values typically result in skewed distributions (Rachlin et al., 1991). Correlational analyses were conducted by calculating point-biserial correlation coefficients for gender and Pearson correlation coefficients for the continuous variables. The statistical significance level was set at 0.05.

## 3. Results

The upper panel of Fig. 1 shows mean EFI scores for the TWD (dark gray bars) and Non-TWD (light gray bars) groups as a function of the subscales of the EFI. To make the scores of the subscales and those of the total directly comparable, the raw scores were transformed into standardized scores with the minimum and maximum set to 0 and 1.0, respectively. The error bars represent the standard error of the mean. The levels of executive function on all subscales and the total score were higher in Non-TWD group than in TWD group. A matched-sample *t* test revealed a significant difference between groups for Strategic Planning, $t(19) = 2.34$, $p = 0.030$, $d = 0.52$, Impulse Control, $t(19) = 3.57$, $p = 0.002$, $d = 0.80$, and EFI Total, $t(19) = 3.55$, $p = 0.002$, $d = 0.79$, but no significant differences were revealed for Motivational Drive $t(19) = 1.47$, $p = 0.158$, $d = 0.33$, Organization, $t(19) = 2.07$, $p = 0.053$, $d = 0.46$, and Empathy, $t(19) = 1.06$, $p = 0.301$, $d = 0.24$.

The middle panel of Fig. 1 shows mean BIS scores. The details are the same as in the top panel. The BIS scores on all subscales and the total were higher in TWD group than in the Non-TWD group. A matched-sample *t* test revealed a significant difference between groups for Attention Impulsivity, $t(19) = –2.77$, $p = 0.012$, $d = 0.62$, Motor Impulsivity, $t(19) = –3.78$, $p = 0.001$, $d = 0.85$, Non-Planning, $t(19) = –2.43$, $p = 0.025$, $d = 0.54$, and BIS Total, $t(19) = –4.21$, $p< 0.001$, $d = 0.94$.

The lower panel of Fig. 1 shows mean MCQ scores. The details are the same as in the top panel, except that the MCQ scores are natural-log transformed. The MCQ scores on all subscales and the total were higher in the TWD group than in the Non-TWD group, although a matched-sample *t* test revealed no significant difference between groups for Small Reward, $t(19) = –0.66$, $p = 0.517$, $d = 0.15$, Medium Reward, $t(19) = –0.19$, $p = 0.852$, $d = 0.04$, Large Reward, $t(19) = –0.06$, $p = 0.951$, $d = 0.01$, and MCQ Total, $t(19) = –0.256$ $p = 0.583$, $d = 0.12$.

Table 2 shows Pearson and point-biserial correlation coefficients of the demographic characteristics and the EFI, BIS, and MCQscores. Because assigning students to the TWD and Non-TWD groups based on 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 three variables of interest were conducted with the total sample of participants (*N*=100). As shown in the table, TWD frequency was significantly correlated with both EFI and BIS scores, but not with the MCQ score. These findings are consistent with the group differences found on these measures as shown in Fig. 1. Other noteworthy findings include: (a) a significant negative correlation between the frequency of texting while driving and the perceived danger of texting, and (b) a significant positive correlation between the perceived danger of texting while driving and the EFI but not between the perceived danger and the BIS.

## 4. Discussion

The present study investigated the relations among the frequency of texting while driving, levels of executive function, and impulsivity. The TWD group showed significantly lower levels of executive function as measured by the EFI than the Non-TWD group. The TWD group showed higher levels of impulsivity than the Non-TWD group, although the difference was statistically significant only for the BIS. These results are consistent with previous research (Pope et al., 2017) and support a general conclusion that drivers with lower levels of executive function and higher levels of impulsivity are more likely to text while driving.

The present results are also consistent with previous studies that examined the relation between self-reported measures of impulsivity and self-control and the frequency of texting while driving (Lantz and Loeb, 2013; Panek et al., 2015; Quisenberry,2015; Struckman-Johnson et al., 2015). With respect to the behavioral measure of impulsivity as assessed by delay discounting of *hypothetical monetary rewards,* however, the present findings that there was no significant relation between a behavioral measure of impulsivity and the frequency of texting while driving are consistent with Hayashi et al.'s (2016) study but inconsistent with Hayashi et al.'s (2015) study. It is important to note that when a behavioral measure of impulsivity was assessed by delay discounting of *social rewards* in Hayashi et al. (2016), a significant relation was found between the frequency of texting while driving and the behavioral measure of impulsivity. These inconsistencies between self-reported and behavioral measures of impulsivity, as well as between different types of rewards to be discounted, have been reported in the literature (e.g., Johnson et al., 2015; Malesza and Ostaszewski, 2016). Taken together, the nature of the relation between the frequency of texting while driving and a behavioral measure of impulsivity is not clear. Further study is needed to identify the source(s) of the discrepancy among these studies.

The present study extends the current literature on executive function to texting while driving. The finding that levels of executive function are lower in drivers who frequently text while driving is consistent with previous studies that showed a link between executive function and various addictive and impulsivity-related problems, such as substance abuse, pathological gambling, obesity, and internet addiction (e.g., Goldstein and Volkow, 2011; Reid et al., 2012; Smith et al., 2011; Zhou et al., 2014). One hallmark of texting while driving is that drivers engage in such a risky behavior despite knowing its potential negative consequences, as demonstrated by the TWD group's high levels of perceived danger of texting while driving in the present study (see also Atchley et al., 2011, for a similar finding). Such a persistent nature is evident in both texting while driving and other addictive and impulsivity-related problems, and this may have an important implication for intervention strategies.

### 4.1. Potential intervention strategies

The similarity between texting while driving and other impulsivity-related problems may suggest that texting while driving shares some key features with these problems. If so, intervention strategies that are effective for these problems may also be effective for texting while driving, although the validity of this extrapolation is essentially an empirical question.

As an example, various forms of Cognitive Behavioral Therapy (CBT) have been shown to be effective for substance abuse (e.g., Dutra et al., 2008), pathological gambling (e.g., Gooding and Tarrier, 2009), and overweight and other eating disorders (e.g., Alvarez-Jimenez et al., 2008; Vocks et al., 2010). One common element for the effectiveness ofvarious CBT-based interventions is to strengthen executive control over impulsivity-related behaviors. In substance abuse treatment, for example, impulsive drug-seeking behavior triggered by drug-related cues is reduced by developing strategies to control craving (Sofuoglu et al., 2013). As an example, the mindfulness-based relapse prevention has been shown to be effective in reducing relapse risk to drug use by increasing awareness and acceptance of negative emotions associated with drug craving (e.g., Bowen et al., 2014). Because individuals who are low in mindfulness are more likely to text while driving (Feldman et al., 2011; Panek et al., 2015), it is possible that mindfulness-based approaches are also effective for texting while driving. Some drivers use texting as a mean to regulate unpleasant emotions or to distract themselves from upsetting feelings (Feldman et al., 2011). The mindfulness-based approaches maybe particularly useful for these types of drivers, although further research is needed to examine the effectiveness of mindfulness-based approaches.

Another treatment that could be effective for texting while driving is executive-function training. It typically consists of repeated practice of the tasks related to various cognitive functions, such as working memory, problem-solving, response inhibition, and visual tracking, for several hours per week over several months (Sofuoglu et al., 2013). Converging evidence has demonstrated the trainability of executive function in children with poor executive functioning (Verbeken et al., 2013). With respect to impulsivity-related problems in adults, previous research has shown that executive-function training is effective for reducing alcohol consumption (Houben et al., 2011a, 2011b) and problematic eating behaviors (Houben and Jansen, 2011; Veling et al., 2011). These findings are consistent with neuroimaging studies showing that executive-function training normalizes regional brain activation in the prefrontal cortex (Wexler et al., 2000) as well as increases the density of dopamine D1 receptors in the prefrontal cortex (McNab et al., 2009), suggesting that the effects of executive function training may be long-lasting. Taken together, although further research is needed to test the hypothesis that executive function training is effective for reducing texting while driving through strengthening executive control, such training is at least a potential intervention strategy for texting while driving.

Finally, there are smartphone applications and devices that block incoming and/or outgoing text messages while driving. AT&T DriveMode®, for example, is such an application that silences an alert of incoming text messages and automatically replies to the messages while driving 15 mph or faster. Creaser et al. (2015) evaluated the effectiveness of a similar application that blocks incoming (but not outgoing) text messages while driving in novice drivers. They found that, throughout the period of the study, the number of text messages sent per mile driven was approximately 4–10 times lower in the treatment groups with the application installed on their cell phone than the control group without the application. It is important to note, however, that 15% of the drivers in the treatment groups tried to bypass the blocking system. This may suggest that behavioral engagement strategies are necessary to introduce and maintain the use of such applications (Delgado et al.,2016). For example, installing a blocking application and turning it on before driving can be conceptualized as a precommitment strategy (Rachlin and Green, 1972) that allows drivers to commit to the safer choice of not texting while driving. Incentivizing those choices in some way (e.g., reduction in insurance premium) may be needed to maximize the successful implementation of the blocking system.

### 4.2. Executive function as an overarching construct

As mentioned previously, research has identified several psychological factors that are associated with texting while driving: attitudes (e.g., Bayer and Campbell, 2012), risk perceptions (e.g., Struckman-Johnson et al., 2015), impulsivity (e.g., Quisenberry, 2015), and regulation of emotions (e.g., Pearson et al., 2013). These psychological factors appear to be independent of and unrelated to each other, however, one potential overarching construct that may underlie these psychological factors is executive function.

First, one essential element of executive function is response inhibition (Barkley, 1997), which refers to “the ability (or inability) to stop a prepotent response, i.e. a response that the individual is ready to emit” (de Wit, 2009). Such ability is directly relevant not only to attitudes toward texting, such as texting dependency and automaticity of texting, but also to impulsivity and lack of self-control. For example, when drivers receive a text message while driving, they need to suppress the behavior of reaching for their cell phone and reading the message—a behavior that can occur automatically. The failure to suppress this behavior is often referred to as dependent, addictive, and impulsive.

Second, with respect to perceived risk of texting while driving, the present results showed a significant positive correlation between levels of executive function and perceived danger of texting while driving: Students with higher levels of executive function are more likely to perceive the greater danger of texting while driving (Table 2). This finding suggests the importance of executive function in the perceived danger of texting while driving. In addition, previous research has shown that the frequency of risky decisions was correlated with executive function (Brand et al., 2005): Individuals with lower levels of executive function are more likely to make risky decisions.

Finally, executive function may play an important role in regulating emotions in the context of texting while driving. For example, to inhibit the behavior of replying to a text message received, drivers need to cope with negative emotion caused by not replying to the message immediately. Previous research has shown that a cognitive process of regulating affect and arousal is theoretically linked to executive function (Reid et al., 2012) and that individual differences in executive function predicts successful emotion regulation (Schmeichel and Tang, 2015).

Taken together, although previous research has made important progress in identifying psychological factors that predict the frequency of texting while driving, synthetizing and unifying these factors into a single construct is of great significance. Future research should examine the possibility of executive function as a potential candidate for unifying these factors. Although this is still a preliminary statement that certainly requires further research, attempts at unifying the underlying factors should facilitate a more comprehensive understanding of the cognitive processes underlying texting while driving and the development of more effective prevention strategies.

### 4.3. Limitations

Several limitations of the present study are noteworthy. First, the use of a cross-sectional design limits the ability to make inferences about how executive function is related to the frequency of texting while driving. For example, it is not clear whether a deficit in executive function causes an increased frequency of texting while driving, or whether excessive cellphone use, including cellphone use while driving, causes impaired information processing skills that impacts various cognitive abilities (Ferraro et al., 2012). In addition, it is possible that the relation between levels of executive function and the frequency of texting while driving is mediated or moderated by other variable(s). The present study is an initial attempt to explore population differences between drivers who frequently text while driving and drivers who infrequently text while driving in terms of levels of executive function and impulsivity, and thus we did not focus on the exact nature of the relation between levels of executive function and the frequency of texting while driving by, for example, employing some forms of regression analyses. Nevertheless, this is an important next step for future research to further our understanding of the role of executive function in texting while driving.

Second, self-reported measures were used to assess levels of executive function. Self-reported measures are subjective in nature, and the accuracy of such measures is entirely based on the individuals' self-evaluation of their own behaviors across different settings over long periods of time (Spinella, 2005). Performance-based measures of executive function, such as those obtained by the stop signal task (Aron, 2007), can be more objective because such measures do not require the individuals' self-evaluation. These objective measures, however, often lack ecological validity because they are obtained in a controlled environment (Spinella, 2005). In contrast, self-report measures can provide unique information about an individual's levels of executive function that are more typical in their everyday situations. In some clinical cases, self-reported measures of executive function have revealed deficits that performance-based measures failed to identify (Reid et al., 2012). Therefore, obtaining self-reported and performance-based measures of executive function are likely to reveal different aspects of an individual's levels of functioning (Toplak et al., 2013) and thus these measures should be considered mutually supportive. Future research that uses performance-based measures would be useful complements to capture different dimensions of executive function.

Third, the frequency of texting while driving was based on self-reported data as well. Previous research has documented the tendency to underreport socially inappropriate behavior (Wentland, 1993). With respect to seat belt use, for example, Parada et al. (2001) compared observational and self-reported data and found that self-reported seat belt use exceeded observed use—75% of drivers reported always using seat belts, but only 61.5% of drivers were observed wearing their seat belts. Collecting observational data of actual texting behavior using an on-board camera (e.g., Klauer et al., 2014) would have been ideal, but we believe that this limitation does not cause a serious challenge to the present conclusions. The tendency to underreport the frequency of texting while driving would have led to erroneously assigning students who frequently text while driving to the Non-TWD group, making it more difficult to reject the null hypothesis that the two groups did not differ in levels of executive function. Therefore, based on the statistically significant difference obtained between the groups, use of the self-reported data in the present study does not appear to have caused a serious issue. Nevertheless, conducting naturalistic driving studies that involve objective recordings of texting behavior would be an improvement for future studies.

Fourth, the participants might have not been blind to the purpose of this study. Particularly, the use of the questionnaires on their frequency and perceived danger of texting while driving made the participants aware that the study was about texting while driving, which might have affected the manner in which they answered subsequent questionnaires on executive function and impulsivity. Again, the use of performance-based measures of executive function and observational data of texting frequencies, which could make the purpose of the study less clear, may be an important next step.

Finally, the sample size was relatively small and exclusively consisted of college students tested in a classroom setting. Although the generalizability of the present findings is limited, the exploratory nature of the present study justifies the relatively small and homogeneous sample. It is nonetheless important to conduct further research to test the external validity of the present finding by including a larger and more diverse sample of drivers. It is important to note, however, that college students are one of the most important target populations at risk for motor vehicle crashes involving texting while driving. In this sense, the exclusive use of college students in the present study can be viewed as both a limitation and a strength (cf. Feldman et al., 2011).

### 4.4. Conclusion

The present study investigated associations among frequency of texting while driving, levels of executive function, and impulsivity in college students. The results show that students who frequently text while driving show low levels of executive function and high levels of impulsivity. These findings are in agreement with findings associated with other addictive and impulsivity- related behaviors, such as substance abuse, pathological gambling, eating disorders, and internet addiction, and thus suggest that intervention approaches effective for these behaviors may also be effective for texting while driving. Additional research should further investigate the utility of conceptualizing executive function as an overarching construct that underlies various psychological factors associated with texting while driving.

These efforts will lead to a more comprehensive understanding of texting while driving and effective strategies to prevent and reduce the problem.

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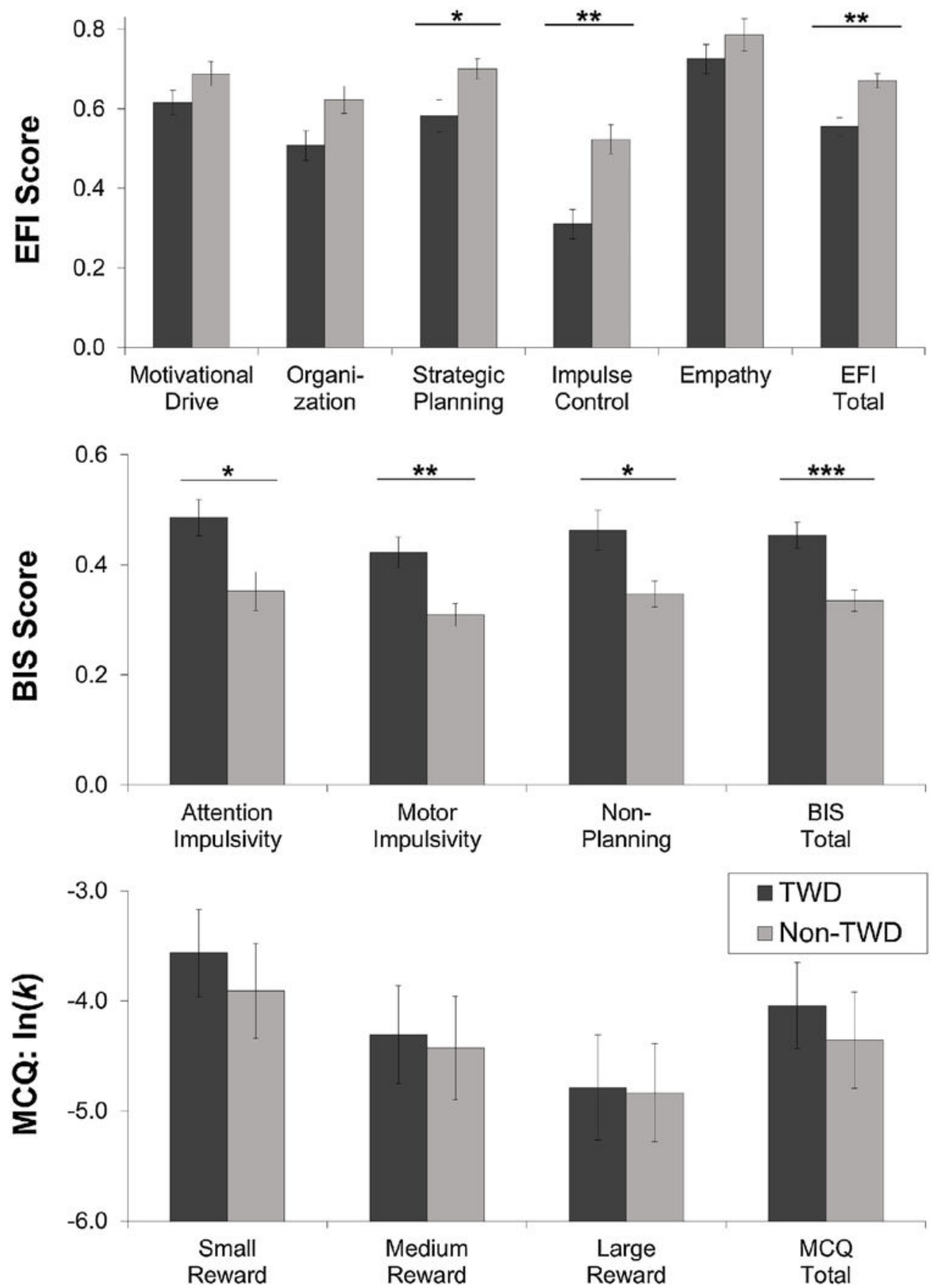


**Fig. 1.**

Mean EFI scores (top panel), BIS scores (middle panel), and natural-log transformed *k* values from the MCQ for TWD (dark gray bars) and Non-TWD (light gray bars) groups as a function of subcategories for each questionnaire. The error bars represent the standard error of the mean. *$p$ <0.05. **$p$ <0.01. ***$p$ <0.001.

## Table 1

Demographic characteristics for TWD and Non-TWD groups.

| | TWD | | | | | | Non-TWD | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pair** | **Gen** | **Age** | **Edu** | **Drive** | **Freq** | **Danger** | **Gen** | **Age** | **Edu** | **Drive** | **Freq** | **Danger** |
| 1 | F | 18 | 1.0 | 2.0 | 6.3 | 7.0 | F | 18 | 0.5 | 2.0 | 2.7 | 3.0 |
| 2 | F | 18 | 1.0 | 4.0 | 5.3 | 7.0 | F | 18 | 1.0 | 3.0 | 3.0 | 7.0 |
| 3 | F | 18 | 1.5 | 2.0 | 6.7 | 5.3 | F | 18 | 1.0 | 2.0 | 1.3 | 6.7 |
| 4 | F | 18 | 2.5 | 2.0 | 6.0 | 3.0 | F | 18 | 2.0 | 2.0 | 1.7 | 7.0 |
| 5 | F | 19 | 1.0 | 2.0 | 5.0 | 7.0 | F | 19 | 0.5 | 2.0 | 2.7 | 4.7 |
| 6 | F | 19 | 1.0 | 4.0 | 5.0 | 5.7 | F | 19 | 1.0 | 3.0 | 1.7 | 7.0 |
| 7 | F | 19 | 1.5 | 3.0 | 5.3 | 7.0 | F | 19 | 1.5 | 3.0 | 2.0 | 7.0 |
| 8 | F | 19 | 1.5 | 4.0 | 6.0 | 7.0 | F | 19 | 2.0 | 4.0 | 2.7 | 5.0 |
| 9 | F | 19 | 2.0 | 3.0 | 6.0 | 4.7 | F | 19 | 2.0 | 3.0 | 2.7 | 7.0 |
| 10 | F | 20 | 2.0 | 4.0 | 5.3 | 7.0 | F | 20 | 2.5 | 3.0 | 2.7 | 7.0 |
| 11 | M | 18 | 0.5 | 2.0 | 5.7 | 7.0 | M | 18 | 1.0 | 1.5 | 2.3 | 7.0 |
| 12 | M | 18 | 0.5 | 2.0 | 5.7 | 7.0 | M | 18 | 0.5 | 3.0 | 2.0 | 7.0 |
| 13 | M | 18 | 1.0 | 2.0 | 5.0 | 3.3 | M | 18 | 1.0 | 2.0 | 2.3 | 4.3 |
| 14 | M | 18 | 1.0 | 2.0 | 7.0 | 3.0 | M | 18 | 1.0 | 2.5 | 3.0 | 6.0 |
| 15 | M | 18 | 1.0 | 2.0 | 5.0 | 7.0 | M | 19 | 0.5 | 3.0 | 1.3 | 5.7 |
| 16 | M | 18 | 1.0 | 2.0 | 7.0 | 6.0 | M | 19 | 1.0 | 3.0 | 1.7 | 6.0 |
| 17 | M | 18 | 1.0 | 3.0 | 5.3 | 7.0 | M | 18 | 1.0 | 3.0 | 2.7 | 6.7 |
| 18 | M | 19 | 2.0 | 3.0 | 5.0 | 5.3 | M | 19 | 1.0 | 3.0 | 1.0 | 4.0 |
| 19 | M | 20 | 1.0 | 4.0 | 6.3 | 6.7 | M | 20 | 1.5 | 3.5 | 2.3 | 7.0 |
| 20 | M | 28 | 0.5 | 6.0 | 5.0 | 5.3 | M | 19 | 1.5 | 5.0 | 2.0 | 6.0 |
| *M* | | 19.0 | 1.2 | 2.9 | 5.7 | 5.9 | | 18.7 | 1.2 | 2.8 | 2.2 | 6.1 |
| *SD* | | 2.2 | 0.5 | 1.1 | 0.7 | 1.4 | | 0.7 | 0.6 | 0.8 | 0.6 | 1.2 |

*Note*: Gen = Gender. Edu = Years of higher education. Drive = Years driving. Freq = Frequency of TWD. Danger = Danger of TWD.

### Table 2

Pearson and point-biserial correlation coefficients of demographic characteristics and measures on executive function and impulsivity with the total sample of participants.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| 1. Age in years | – | | | | | | | | |
| 2. Gender(F = 0) | 0.16 | – | | | | | | | |
| 3. Education | 0.30** | 0.04 | – | | | | | | |
| 4. Years driving | 0.96*** | 0.15 | 0.30** | – | | | | | |
| 5. EFI total | 0.12 | −0.15 | 0.12 | 0.10 | – | | | | |
| 6. BIS total | −0.10 | −0.12 | −0.06 | −0.07 | −0.62*** | – | | | |
| 7. MCQ total | 0.12 | 0.38*** | 0.00 | 0.12 | −0.06 | −0.05 | – | | |
| 8.TWD frequency | −0.11 | 0.15 | 0.00 | −0.05 | −0.29** | 0.20* | −0.01 | – | |
| 9. TWD danger | 0.05 | −0.18 | 0.00 | 0.04 | 0.31** | −0.12 | −0.08 | −0.21* | – |

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.