

Risky Business: Executive Function, Personality, and Reckless Behavior During Adolescence and Emerging Adulthood

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Adolescence is a risky business. Despite outstanding physical health, the risk of injury or death during adolescence is 2–3 times that of childhood. The primary cause of this increase in morbidity and mortality is heightened risky behavior including drinking, driving, drug-taking, smoking, and unprotected sex. Why is it that some adolescents take big risks, while others do not? One potential source of individual differences in risk-taking behavior may lie in individual differences in executive function including judgment, impulse control, self-monitoring, and planning. Researchers have hypothesized that limited brain system integration and efficiency, particularly in the prefrontal cortex and related structures, may be involved in the range and degree of risky behavior commonly exhibited by teens. In the present study, we examined the relation between risky behavior, personality factors, and performance on neuropsychological tests of executive function. The community sample of 136 adolescents aged 13- to 17-years-old and 57 emerging adults aged 18- to 22-years-old exhibited marked individual differences in risk-taking behavior; participants' scores on a alcohol, smoking, drugs, sex, driving, and antisocial behavior questionnaire ranged from 0 to near the maximum value possible. We found that risky personality and performance on the neuropsychological tests were both significant predictors of real-world risk-taking. These data have important implications for current public policies involving adolescents and emerging adults.

Keywords: adolescence, risky behavior, executive function, personality

The transition between childhood and adulthood is characterized by a remarkable developmental paradox—despite a substantial increase in both physical maturity and cognitive ability, there is also a dramatic increase in morbidity and mortality. Some statistics indicate that mortality rates during adolescence increase by as much as 200% from middle childhood (Dahl, 2004; Spear, 2000). This increase in morbidity and mortality has, in part, been attributed to a sharp rise in risky and antisocial behavior during adolescence (Arnett, 1992; Moffitt, 1993). For example, adolescents are more likely than both children and adults to abuse alcohol, use illicit substances, have unprotected sex, commit antisocial acts, drive recklessly, and drive while intoxicated (Steinberg, 2004).

But why do adolescents engage in risky behavior? For some researchers, and indeed for many concerned members of the general public, the hormonal changes that accompany puberty are thought to be responsible for reckless or risky adolescent behavior (Dahl, 2004). Consistent with this view, some researchers have

documented an association between the timing of puberty and the emergence of risk-taking and delinquent behaviors. Although early puberty is related to increased risk involvement (Caspi, Lynam, Moffitt, & Silva, 1993; Martin et al., 2002; Williams & Dunlop, 1999), the situation is complicated by the mediating role of experience. For example, Caspi et al. (1993) found that, although girls who entered puberty earlier were more likely to engage in antisocial behaviors at age 15 than girls who entered puberty later, this effect was only apparent for those girls who attended mixed-sex schools. Furthermore, the notion that only those who enter puberty early are prone to risk-taking has also been questioned. Williams and Dunlop (1999), for example, found that male adolescents who begin puberty either early or late relative to age-based norms report higher levels of risk-taking and delinquency, especially in the form of school opposition behaviors and crime. These researchers propose that those who enter puberty early might engage in higher levels of risk-taking as a result of advanced peer group activities, whereas those who enter puberty late may do so as a means of raising self-esteem and gaining popularity among peers.

Researchers have also proposed that pubertal hormones may make a contribution to adolescent emotional volatility (Miller, Buchanan, Eccles, & Becker, 1992) and negative moods (Brooks-Gunn, Graber, & Paikoff, 1994). Although individual differences in levels of androgenic hormones, coupled with individual differences in experience, have been related to variations in the development of adolescent sexual behavior (Udry, 1988), there is little evidence for a simple connection between pubertal increases in hormones and increases in other forms of risk-taking behavior (Dahl, 2004; Spear, 2000; Spear, 2010). In fact, Dahl (2004) has argued that there is no causal link between hormones and risk-

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taking, and in many studies, individuals with the highest levels of pubertal hormones have exhibited little or no behavioral problems.

Given that the link between adolescent risk-taking and pubertal hormone levels is at best tentative, researchers are now focusing on other explanations for this phenomenon. One potential explanation lies in the relation between certain personality factors and adolescent risk-taking behavior. Specifically, aggression, impulsivity, sensation-seeking tendencies, and sociability have all been consistently identified as personality factors that are positively related to adolescent risk-taking (Arnett, 1992; Eysenck, 1990; Stanford, Greve, Boudreaux, & Mathias, 1996; Wagner, 1993; Zuckerman & Kuhlman, 2000; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). For example, Stanford et al. (1996) found that both high school and university students who rated themselves high for impulsivity had greater involvement in real-life risk-taking than did less impulsive individuals. Similarly, other researchers have also reported a positive relation between impulsivity and substance abuse specifically, suggesting that more impulsive individuals tend to use intoxicating substances more frequently (Wagner, 1993; Zuckerman et al., 1993).

In addition to personality traits, the developing adolescent brain may also hold a key to the increase in risk-taking during adolescence. The human brain goes through a number of remarkable changes during adolescence such as increased growth, connectivity, and synaptic pruning (Spear, 2010). There is now a growing body of research showing that the human brain continues to develop until at least 20 years of age (Giedd, 2004; Giedd et al., 1999; Hudspeth & Pribram, 1990; Kelley, Schochet, & Landry, 2004; Toga, Thompson, & Sowell, 2006). Based on these developmental changes, many researchers have begun to explore the potential link between age-related changes in the human brain during adolescence, and adolescents' propensity to engage in risky behaviors (Blum, Cull, Braverman, & Comings, 1996; Casey, Getz, & Galvan, 2008; Gardner, 1999; Kelley et al., 2004; Spear, 2000; Spear, 2010). A number of researchers now propose that individual differences in the rate of development of neural pathways associated with emotional regulation and reward sensitivity (such as the prefrontal cortex and the limbic regions) may help to explain the increase in negative and risky behaviors during adolescence (Blum et al., 1996; Gardner, 1999; Kelley et al., 2004; Spear, 2000).

Many experts agree that the prefrontal cortex is paramount in decision making, emotional regulation, and inhibitory responses (Bechara, Damasio, & Damasio, 2000; Passingham, 1993; Romer, 2010; Spear, 2010; Stuss & Knight, 2002). This area of the brain is intimately involved in our ability to assess the relative risks and rewards of a particular behavior or action (Kelley et al., 2004). For example, patients who suffer from frontal-lobe dysfunction typically perform poorly on tasks that require the inhibition of a particular behavior (Stuss & Knight, 2002). In other words, the prefrontal cortex is a critical component in performing and maintaining inhibitory behaviors and thoughts (Kelley et al., 2004). During the course of normal development, the immaturity of the prefrontal cortex may help to explain the high rate of risky behavior that is exhibited during adolescence and early adulthood (Dahl, 2004; Spear, 2010). Although adolescents conceptually understand the risks associated with their behavior by about the age of 14, the inhibitory mechanisms required to resist those risky behaviors are not equivalent to that of adults until approximately 20 years of age

(Giedd, 2004; Giedd et al., 1999; Sowell, Thompson, Holmes, Jernigan, & Toga, 1999).

Experimentally, there is some evidence for a relation between frontal lobe functioning and risk-taking behaviors. For example, using a Functional MRI scanner (fMRI), Eshel, Nelson, Blair, Pine, and Ernst (2007) found that adolescents displayed decreased frontal cortical activity relative to adults while engaging in a monetary decision-making task; reduced frontal activity was also correlated with increased risk-taking on the task. At this stage, it appears that while adolescents have the physical capability (and often the autonomy) to engage in almost any risky act that they choose, their ability to inhibit potentially risky acts is not equivalent to that of adults (Romer, 2010).

Some researchers have argued that the limbic system is also a contributing factor in adolescent risk-taking behavior (Casey et al., 2008). Citing both animal models and human neuroimaging studies, Casey et al. (2008) have argued that, under conditions of high emotional arousal, adolescents may be more likely to engage in risky behavior because their limbic system "takes over" and they do not have the sufficient prefrontal cortical mechanisms in place to suppress their behavior. Age-related changes in the balance between the limbic system and the prefrontal cortex has also been cited as one reason that risk-taking behavior appears to peak during adolescent development (Casey et al., 2008).

While neurobiological models provide an explanation of potential causal mechanisms underlying the increase in risky-behavior during adolescence, these models do not fully explain the specific cognitive underpinnings of this increase in risk-taking behavior. An important step in understanding the relation between brain and behavior during adolescence is to study the cognitive processes that are thought to reflect these observed changes in neurobiology. Researchers now agree that a major dimension of cognitive development during adolescence is enhanced executive function (Keating, 2004; Kuhn, 2006). Executive functions refer to the cognitive processes associated with an individual's ability to carry out goal-directed behavior including judgment, impulse control, self-monitoring, and planning (Miller & Cohen, 2001). The adolescent's inability to control reckless behavior is believed to reflect limitations in executive function that are due to immature neural system integration and efficiency, particularly in the prefrontal cortex and related structures (Luna & Sweeney, 2004).

To date, the majority of research on risk-taking and executive function has been focused on clinical populations such as violent adolescent offenders, or adolescents with substance abuse disorders (Patrick, Blair, & Maggs, 2008). In the studies that have incorporated community samples, the results to date have been equivocal, but these studies have also involved somewhat restricted samples. For example, in a study with 10- to 12-year-old schoolchildren, Romer (2010) found that although decreased executive functioning was related to risk-taking behavior, this relation was mediated by the inclusion of sensation-seeking personality. That is, decreased executive functioning was predictive of increased sensation-seeking, which in turn was predictive of risk-taking behavior. In another study with female college students, Patrick et al. (2008) found that higher working memory scores were predictive of increased involvement in alcohol use, drug use, and delinquency, but this effect was only observed in individuals who also reported high levels of reward sensitivity. Furthermore, Patrick et al. (2008) found no effects with a go, no-go task

designed to measure response inhibition—an important aspect of executive functioning.

Given the limited research on community samples in the past, the overarching goal of the present study was to examine the relation between neuropsychological tests of executive function, personality characteristics, and real-life risk-taking behavior across a community sample of adolescents and emerging adults who ranged in age from 13 to 22 years old. Specifically, we examined whether individual differences in executive function would independently predict real-life risk-taking behavior after taking into account participants' personality traits.

Method

Participants

A total of 136 (69 males, 67 females) 13- to 17-year-old adolescents (mean age = 15.86 years, $SD = 1.06$ years), and 57 (27 males, 30 females) 18- to 22-year-old emerging adults (mean age = 19.80 years, $SD = 1.41$ years) were recruited from a moderate-sized city in New Zealand. The initial participants were recruited via word of mouth. These participants were given a flyer after completing the study and were asked to promote the study to friends, siblings, or associates. This snowball recruitment procedure was highly effective in recruiting a diverse sample of participants. For the adolescent sample, for example, all nine secondary schools in the region were represented, and 18 of the participants had dropped out of school permanently. Most of the participants were of New Zealand European descent but they came from a wide range of socioeconomic backgrounds.

Measures

Personality. Participants completed the Zuckerman and Kuhlman Personality Questionnaire–Short Form (ZKPQ-SF; Zuckerman et al., 1993). The ZKPQ-SF consists of 35 true/false questions and generates five personality ratings: Impulsive Sensation-Seeking (ImpSS), Neuroticism-Anxiety (*N-Anx*), Aggression-Hostility (Agg-Host), Activity (Act), and Sociability (Sy). The ZKPQ is a robust five-factor personality questionnaire that has been used extensively in research on risky personality traits (Zuckerman, 2008). A number of studies have documented good construct validity between the ZKPQ and a number of risky behaviors such as smoking, drinking, drug abuse, sex, and gambling (Zuckerman, 2002; Zuckerman, 2007, 2008; Zuckerman & Kuhlman, 2000). Prior research has shown that high scores on the ImpSS, Agg-Host, and Sy categories are indicative of a high risk-taking personality type (Zuckerman & Kuhlman, 2000). Furthermore, ratings of a given individual by friends, relatives, and spouses are highly consistent (Angleitner, Rieman, & Spinath, 2004; Goma-i-Freixanet, Wisemeijer, & Valero, 2005).

Risk-taking. Participants completed a 3-part self-report questionnaire, the Life Experiences Questionnaire (LEQ), which was designed to assess the degree of risk-taking behavior that they had engaged in during their lifetime. The first part of the LEQ consisted of the Zuckerman and Kuhlman Life Experiences Questionnaire (ZK-LEQ; Zuckerman & Kuhlman, 2000). Participants were asked to answer questions about their degree of involvement in five areas of risky behavior: cigarette smoking (4 items, e.g., “At

what age did you begin smoking?”), drug use (4 items, e.g., “How often have you used marijuana or hashish during the past year?”), sexual behavior (3 items, e.g., “With how many different persons have you had sexual intercourse with during the last 12 months?”), driving an automobile (6 items, e.g., “Have you ever driven at a speed in excess of 20 kmph over the legal speed limit?”), and being a passenger in an automobile (4 items, e.g., “How often have you been a passenger in a car with an unlicensed, or a learner/restricted-licensed driver who is breaking the conditions of their license?”). The original ZK-LEQ has been validated in conjunction with the ZKPQ, and it has consistently been found that individuals who score higher on the ZK-LEQ (therefore engaging in more real-life risk) score higher on risky personality traits as defined by the ZKPQ (Zuckerman & Kuhlman, 2000).

The second part of the LEQ comprised a modified and shortened version of the Self-Report Early Delinquency scale (SRED; Moffitt & Silva, 1988), which was originally designed to capture self-reports of illegal and antisocial behaviors from New Zealand adolescents. The SRED has been shown to be an accurate self-report tool for identifying individuals engaging in delinquent behaviors (Moffitt & Silva, 1988). The Modified Self-Report Early Delinquency scale (M-SRED) consisted of 9 items, which assessed participants' degree of involvement in the areas of school delinquency, vandalism and sabotage, theft, trespass, fighting and weapons use, and animal cruelty.

The third part of the LEQ consisted of the Alcohol Use Disorders Identification Test (AUDIT; World Health Organization, 1992), which is designed to assess a respondent's level of alcohol use. The AUDIT is a screening questionnaire designed to identify individuals who display a pattern of alcohol consumption and alcohol-related behavior that is hazardous to their personal health. The AUDIT has been shown to have excellent discriminant validity with the ability to distinguish between hazardous and nonhazardous levels of alcohol abuse, as well as symptoms of alcohol dependence (Saunders, Aasland, Babor, De La Fuente, & Grant, 1993). Furthermore, the AUDIT has been tested for validity and reliability in both clinical and community samples within a number of different international settings (World Health Organization, 1992).

Neuropsychological testing. Each participant also completed a battery of neuropsychological tests selected to assess aspects of executive function and impulse control that are thought to be related to prefrontal cortical development. The test battery consisted of a modified version of a 5-test battery originally employed by Glisky, Poulster, and Routhieaux (1995) and more recently by Butler, McDaniel, Dornburg, Price, and Roediger (2004). In the present study, a 6-test battery was employed which included the total number of words generated on the Controlled Oral Word Association Test, using the letters ‘F,’ ‘A,’ and ‘S’ (COWAT; Benton & Hamsher, 1976), the Mental Control and Backward Digit Span scores from the Wechsler Memory Scale-III (WMS-III; Wechsler, 1997b), the Mental Arithmetic score from the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997a), perseverative error score from the Wisconsin Card Sorting Test (WCST: CV4; Heaton & Goldin, 2005), and reaction time and error score from a modified, computer version of the Stroop Color-Word Test (Stroop, 1992). The 5-test battery originally employed by Glisky et al. (1995) has been shown to load strongly on a single factor which is believed to be indicative of prefrontal cortical functioning

(Glisky et al., 1995), and numerous researchers have since reported a relation between performance on the 5-factor battery and prefrontal cortical functioning (Butler et al., 2004; Glisky, Rubin, & Davidson, 2001; McDaniel, Glisky, Rubin, Guynn, & Routhieaux, 1999). Furthermore, the Stroop Color-Word Test is believed to rely on a number of cognitive processes associated with executive functions including the processes of selective attention and impulse control (Pachana, Thompson, Marcopulos, & Yoash-Gantz, 2004).

Procedure

When participants arrived at the laboratory, they were shown to a room that contained a computer desk, a computer, and two chairs. They were told that they would be taking part in a study investigating risk-taking behavior. After providing informed consent, participants were administered the neuropsychological battery. The COWAT, WMS-III, and WAIS-III subtests were administered orally by a clinically trained experimenter who was present in the room with the participant, the experimenter then left the room and the participant was presented with the WCST: CV4, and Stroop tasks on a computer.

Once the neuropsychological tests were completed, the participants completed the LEQ and ZKPQ-SF questionnaires in private, and then placed them into a locked box. The participants were specifically reminded that their names did not appear on the questionnaires and that data tracking was carried out through arbitrarily assigned participant numbers and could not be linked to their name. Participants were also told that the locked box would only be opened once the study was complete. These procedures were used to encourage participants to answer the questionnaires as honestly as possible.

Coding

Participants' responses on the AUDIT, ZKPQ-SF, and the neuropsychological tests were all coded in line with the guidelines provided for each respective measure (AUDIT: World Health Organization, 1992; ZKPQ-SF: Zuckerman et al., 1993; COWAT: Benton & Hamsher, 1976; WMS-III: Wechsler, 1997b; WAIS-III: Wechsler, 1997a; WCST: CV4: Heaton & Goldin, 2005).

Participants' scores on part one of the LEQ were obtained by allocating scores on a 5-point scale ranging from zero to four for each section item. A score of four was given for high-end risk-taking, while a score of zero constituted no presence of risk-taking behavior. For example, on one of the Driving items, participants were asked how often they had driven without a license or broken the conditions of a learners or restricted license. If participants answered 'never,' then they received a score of zero, as no risk was associated with this behavior. Conversely, participants who responded '7 or more times' received a score of four as there was deemed to be high risk associated with this behavior.

The scoring of participants' responses on the second section of the LEQ (the M-SRED) was conducted in a similar manner to the scoring of part one of the LEQ, although the scale options differed in order to match the different item response options. For example, on the Vandalism item, participants were asked if they had ever illegally damaged property; three responses were possible: 'never,'

'yes—once,' or 'yes—more than once.' These responses received scores of 0, 2, and 4, respectively.

Results

Self-Reported Risk-Taking

The first step in the analysis was to examine whether there were age-related or gender-related differences in participants' self-reported involvement in real-life risk-taking behavior as measured by the LEQ. A series of 2 (Age: adolescent, emerging-adult) \times 2 (Sex: male, female) analyses of variance (ANOVAs) were conducted over all items from the LEQ.¹ Table 1 provides a summary of participants' scores on the Life Experiences Questionnaire (LEQ) as a function of age and sex. On average, participants in our sample reported relatively high levels of risk-taking as measured by the LEQ. Participants' scores on questions regarding alcohol, smoking, drug use, sexual behavior, risky driving, being the passenger of a risky driver, and antisocial behavior ranged from 0 up to 89% of the maximum possible score.

Furthermore, as shown in Table 1, there were a number of significant sex differences on the LEQ. Males in our sample reported significantly higher levels of smoking, drug use, risky driving, being the passenger of a risky driver, alcohol use, antisocial behavior, and overall risk-taking as measured by the composite LEQ score. There were also a number of significant age-related differences on the LEQ. Adolescents reported higher levels of smoking, and overall risk-taking compared to the emerging adults, while the emerging-adults reported higher levels of risky driving, and involvement in antisocial behavior. There were no significant interaction effects.

Relation of Risky Behavior to Personality and Neuropsychological Functioning

The next step in the analysis was to examine potential relations between participants' level of risky behavior and their scores on the personality and neuropsychological assessments. First, to allow measures with different scales to be compared, participants' raw scores were converted to z-scores.² Following this conversion, three composite scores for each participant were calculated: (a) a composite score for the LEQ was calculated by averaging a participant's z-scores on all of the sections of the questionnaire; (b) a composite score for the ZKPQ-SF was calculated by averaging a participant's z-scores on the ImpSS, Agg-Host, and Sociability scales of the ZKPQ-SF; and (c) a composite score on the neuropsychological functioning battery was calculated by averaging

¹ We have used Cohen's (1988) measures of effect size to indicate the meaningfulness of significant effects; for *F* tests and *t* tests, effect size = *d*; for correlations, effect size = the value of the correlation coefficient, *r*. According to Cohen, effect sizes of *d* = .20 or *r* = .10 indicate a "small" effect, effect sizes of *d* = .50 or *r* = .30 indicate a "medium" effect, and effect sizes of *d* = .80 or *r* = .50 indicate a "large" effect.

² To calculate z-scores, we took the individual raw scores to be standardized, subtracted the mean population score for that measure, and divided the result by the standard deviation of the population. [z-score = (raw score to be standardized – mean score of the population)/standard deviation of the population].

Table 1
Means (Standard Errors), Ranges, F values, and Effect Sizes (D) for Participants on the Life Experiences Questionnaire (LEQ) as a Function of Gender, and Age Group

Measure	Max	Males (n = 96)		Females (n = 97)		F	d	Adolescents (13–17 yrs; n = 136)		Emerging-adults (18–22 yrs; n = 57)		F	d
		Mean	Range	Mean	Range			Mean	Range	Mean	Range		
Smoking	14	4.17 (.49)	0–14	3.14 (.47)	0–14	3.96*	.29	4.38 (.43)	0–14	1.93 (.47)	0–12	10.87**	.48
Drugs	16	4.21 (.41)	0–16	2.70 (.36)	0–13	13.88**	.54	3.40 (.32)	0–16	3.58 (.54)	0–14	.24	—
Sexual Behavior	12	2.50 (.27)	0–11	1.95 (.29)	0–10	3.23	—	2.11 (.25)	0–11	2.49 (.32)	0–8	.92	—
Driving	24	6.94 (.60)	0–21	3.27 (.42)	0–18	32.63**	.83	4.16 (.42)	0–19	7.32 (.78)	0–21	19.05**	.63
Passenger	16	7.80 (.45)	0–16	4.63 (.40)	0–16	29.31**	.78	6.29 (.40)	0–16	6.02 (.55)	0–16	.04	—
Alcohol (AUDIT)	40	14.07 (.71)	0–33	10.82 (.84)	0–31	7.34**	.39	12.20 (.66)	0–33	13.02 (1.06)	1–27	.59	—
Antisocial	34	12.35 (.78)	0–34	7.01 (.62)	0–26	40.47**	.92	9.09 (.63)	0–34	11.05 (.98)	0–29	4.53*	.31
Total LEQ	156	48.14 (3.36)	2–139	29.99 (2.61)	0–99	26.06**	.74	41.62 (2.47)	0–139	32.39 (3.04)	1–84	4.28*	.30

* $p < .05$. ** $p < .01$.

participants’ z-scores on each of the six neuropsychological measures (Neuro-Function). Because there were a number of significant age and sex differences on the LEQ, we conducted partial Pearson Product-Moment correlations between participants’ scores on the LEQ, the ZKPQ-SF, and the neuropsychology battery while controlling for age and sex. Figure 1 illustrates the correlation between real-world risky behavior (LEQ), risky personality (ZKPQ-SF), and the neuropsychological functioning battery (Neuro-Function) while controlling for age and sex. The zero-order correlations that are depicted in Figure 1 were calculated from composite z-scores.

As shown in Figure 1, measures of real-world risky behavior, risky personality, and neuropsychological functioning were all significantly correlated. In addition, neuropsychological test scores were negatively related to risk-taking; that is, as participants’ scores on the neuropsychological tests increased, their scores on the real-world risk-taking measure decreased. Finally, the largest correlation was observed between the ZKPQ-SF personality measure and self-reports of real-world risky behavior (LEQ), $r = .61$, $p < .01$. Specifically, as levels of impulsivity, sensation-seeking, aggression, and sociability increased, so too did risky behavior across the multiple risk areas assessed. Because participants who engaged in high levels of risk-taking behavior also tended to have

risky personalities, we conducted an additional partial correlation between LEQ and Neuro-Function while controlling for age, sex, and ZKPQ-SF. The negative correlation between participants’ scores on the Neuro-Function measure and their scores on the LEQ remained statistically significant ($r = -.22$, $p < .01$).

Predictive Analysis

While there was a significant correlation between participants’ Neuro-Function scores and the LEQ, a stronger relation existed between LEQ and ZKPQ-SF ($r = .63$). Additionally, Neuro-Function scores were also significantly related to ZKPQ-SF ($r = -.26$). It was, therefore, important to ascertain whether performance on the Neuro-Function battery explained any unique variance in LEQ scores beyond that explained by risky personality (ZKPQ-SF). To do this, we conducted a hierarchical regression analysis to test the differential prediction of the neuropsychology battery (Neuro-Function) and risky personality (ZKPQ-SF) for real-world risk-taking behavior (LEQ). Our question here was whether the Neuro-Function battery would be uniquely predictive of real-world risk-taking once risky personality (ZKPQ-SF) was taken into account. When predicting LEQ score, we entered the ZKPQ-SF score, age, and sex as the first step in order to clearly illustrate the variability in LEQ score accounted for by the ZKPQ-SF. Participants’ scores on the neuro-function battery were entered in the second step of the regression to then examine the unique predictive power of the neuropsychology battery. In predicting real-world risk-taking, the model was significant overall, $F(4, 192) = 43.97$, $p < .01$. Although a large proportion of the variance in LEQ was accounted for by ZKPQ-SF and sex, performance on the Neuro-Function battery was found to be uniquely predictive of participants’ real-life risk-taking even once risky personality, age, and sex were taken into account. Table 2 shows the results of this regression analysis.

Discussion

The primary aim of the present study was to examine the relation between participants’ scores on a neuropsychological battery of executive function, their personality profiles, and their

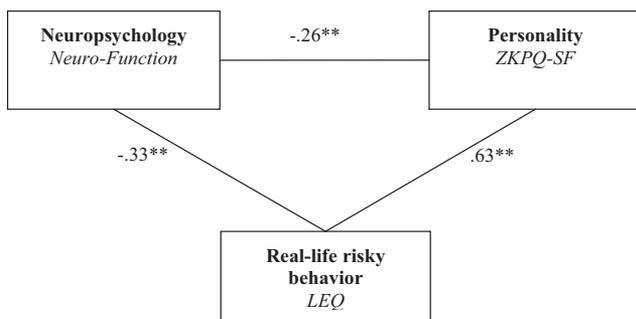


Figure 1. Pearson product-moment correlations between participants’ z-scores on the personality measure (ZKPQ-SF), the Neuropsychological functioning battery (Neuro-Function), and their real-life risky behavior (LEQ) after controlling for age and sex. ** $p < .01$.

Table 2
Hierarchical Regression Analysis for Variables Predicting Real-World Risk-Taking Behavior as Measured by the LEQ

Predictor variable	B	SE B	β
Step 1			
Constant	.21	.13	
ZKPQ-SF	.68	.06	.60**
Age	.02	.09	.01
Sex	-.45	.08	-.29**
			$R^2 = .46^{**}$
Step 2			
Constant	.20	.13	
ZKPQ-SF	.62	.06	.56**
Age	.02	.09	.01
Sex	-.44	.08	-.28**
Neuro-Function	-.22	.07	-.17**
			$R^2 = .48^{**}$
			$\Delta R^2 = .02$

Note. Final β weights are reported throughout.

* $p < .05$. ** $p < .01$.

involvement in real-life risky behavior in a community sample of adolescents and emerging-adults. Consistent with prior research (Arnett, 1992; Eysenck, 1990; Stanford et al., 1996; Wagner, 1993; Zuckerman & Kuhlman, 2000; Zuckerman et al., 1993), we found that personality traits of impulsivity, sensation-seeking, aggression, and sociability were related to increased levels of risky behavior. Furthermore, consistent with current views about neurological and behavioral development during adolescence, we found that individual differences in performance on a Neuro-Function battery were uniquely predictive of participants' real-life risky behavior above and beyond the variation that was accounted for by personality, age, and sex.

It is widely established that the frontal lobe, and in particular, the prefrontal cortex, is involved in the inhibition of behavior (Giedd, 2004). Our finding that those participants who scored lower on the neuropsychological battery engaged in higher levels of risky behavior than did individuals who scored higher on the neuropsychological battery provides empirical support for the view that adolescents' reckless behavior may be a symptom of developmental changes in the prefrontal cortex and in the integration between the prefrontal cortex and related structures (Giedd, 2004; Luna & Sweeney, 2004). Our data suggest that, during a large part of the adolescent period, the brain's inhibitory system does not match the demands of the excitatory or sensation-seeking systems, resulting in increased participation in risky behaviors (Steinberg, 2004).

Many cognitive skills, such as memory and processing speed, have been shown to improve with age up to mid-adolescence when adult capabilities are attained (Kuhn, 2006). The neuropsychological battery used in the present study included individual tasks that were designed to assess a number of executive, or self-regulatory, cognitive skills. One potential criticism of the present research is that the neuropsychological battery we used was simply a measure of general intelligence. That is, individual differences in participants' scores may be due to general differences in cognitive efficiency rather than to differences in prefrontal function per se. Put another way, those who are greater risk-takers may simply be less intelligent than those who take fewer risks. This possibility

appears less likely in light of previous research on the relation between tests of IQ and executive function. For example, Ardila, Pineda, and Rosselli (2000) found few significant correlations between the performance of adolescents on the Wechsler Intelligence Scale for Children-Revised (WISC-R) and their performance on a number of executive function tests including the Wisconsin Card Sort Test (see also Glisky et al., 1995). Furthermore, research in our laboratory has shown that participants' scores on the National Adult Reading Test: Second Edition (NART; Nelson & Willison, 1991), a brief estimate of intellectual functioning, is not predictive of real-life risk-taking as measured by the LEQ (Graham, 2010). It appears, therefore, that the relation between neuropsychological functioning and risk-taking behavior found in the present study is more complex than basic intelligence.

Another potential limitation of the present research is that we did not directly measure participants' neurological functioning, and instead relied on their performance on a battery of neuropsychological tests. It is important to note, however, that the neuropsychological battery that we used in the present experiment included a number of tasks that have been shown to be sensitive to changes in the prefrontal cortex that occur during aging (Glisky et al., 1995). Furthermore, several neuroimaging studies have also shown increased prefrontal cortical activation in patients performing these particular neuropsychological tasks (Cabeza & Nyberg, 2000; Hoshi et al., 2000; Smith, Taylor, Brammer, & Rubia, 2004; Warburton et al., 1996).

Taken together, our findings suggest that executive control plays an important role in risk-taking behavior during adolescence (see also, Kuhn, 2006). This finding is highly consistent with a growing body of research showing that executive function, particularly during early adolescence, might serve as a risk factor for risky behaviors. For example, Aytaclar, Tarter, Kirisci, and Lu (1999) found that poor executive functioning played a crucial role in the development of early drug use during adolescence. Similarly, Caspi, Henry, McGee, Moffitt, and Silva (1995) found that executive function deficits during adolescence were related to the development of conduct problems that persisted into adulthood. Recently, Moffitt et al. (2011) examined the relation between childhood self-regulatory skills and adult adjustment in a birth cohort that had been followed from the age of 5 to 32 years old. Specifically, they tested whether childhood self-control would independently predict adulthood health, wealth, and crime above and beyond that accounted for by variables of socioeconomic status and IQ. They found that poor self-control during childhood and early adolescence was independently predictive of poor physical and mental health, decreased financial success in adulthood, and increased propensity for criminal behavior during late adolescence and into adulthood. Taken together, the data presented here and the data reported by others (Aytaclar et al., 1999; Caspi et al., 1995; Moffitt et al., 2011) suggest that inhibitory control is one of the best predictors of adolescent risk-taking.

In addition to enhancing our understanding of the relation between the development of brain and behavior, the present findings also have important implications for social policy and interventions that are designed to minimize morbidity and mortality during adolescence. One potentially valuable initiative that has emerged from research of this kind is the development of new interventions that are designed to increase executive control. For example, the

notion that it might be possible to enhance executive control through training is currently being trialed in New Zealand in an attempt to improve adolescent driving performance (University of Waikato, 2007). Another potentially valuable initiative is the development of new interventions that may help to modify personality factors that are related to risky behaviors. For example, it is possible that the parenting and family contextual factors that have been shown to promote psychopathology in hyperactive-impulsive and aggressive-hostile children (see Keown & Woodward, 2002) may also contribute to risk-taking in adolescents with some temperament styles. This possibility remains to be tested.

The current research adds to a growing body of studies suggesting that adolescents are neurologically inclined toward risk-taking. Most adolescents engage in risky behaviors even though they know the inherent risks of those behaviors (Benthin, Slovic, & Severson, 1993; Beyth-Marom, Austin, Fischhoff, Palmgren, & Jacobs-Quadrel, 1993; Millstein & Halpern-Felsher, 2002; Moore & Gullone, 1996; Quadrel, Fischhoff, & Davis, 1993; Steinberg, 2004), and those adolescents who have impulsive-aggressive personality styles, or have lower neuropsychological ability to suppress inappropriate actions, are more likely to participate in a high degree of risk-taking behavior (Arnett, 1992; Eshel et al., 2007; Eysenck, 1990; Romer, 2010; Stanford et al., 1996; Wagner, 1993; Zuckerman & Kuhlman, 2000; Zuckerman et al., 1993). It is also important to remember, however, that not all forms of risk-taking are necessarily deviant or antisocial. In fact, mainstream society endorses and admires those who take risks in areas such as sports, exploration, or acts of bravery (Moore & Gullone, 1996). These types of activities are considered constructive for adolescent development because they promote self-confidence and independence (Baumrind, 1991). A key task for future research will be to identify new ways to channel adolescent risk-taking down more positive pathways.

There are also a number of other factors that need to be considered when investigating risk-taking during adolescence. Our study focused on risky personality variables, and neuropsychological functioning; future research should also consider the role of emotion regulation, peer and parental influence, and the development of other brain areas, such as the nucleus accumbens (Galvan et al., 2007; Galvan et al., 2006). Also, a vast amount of research on adolescent risk-taking has focused on older high school and university samples; more research with large groups of young adolescents, for example those aged 13–15 years, may provide important information about the development of longer-term, less social, risk-taking behavior. Furthermore, the present study incorporated a cross-sectional developmental approach to examine risk-taking during adolescence. Although cross-sectional research tells us something about the concurrent relation between risk-taking and other individual difference factors, longitudinal studies are paramount to establishing the long-term trajectories of these problem behaviors. A number of excellent longitudinal studies exist both here in New Zealand (such as the Dunedin Multidisciplinary Health and Development Unit and the Christchurch Health and Development Study) and internationally (such as the recently commissioned National Children's Study in North America) which have provided, and will continue to provide, an excellent resource for understanding the antecedents of risk-taking behavior.

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