The Dopamine Receptor D4 Gene (DRD4) and Self-Reported Risk Taking in the Economic Domain

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The Dopamine Receptor D4 Gene (DRD4) and Self-Reported Risk Taking in the Economic Domain

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Abstract

Background: Recent evidence suggests that individual variation in risk taking is partly due to genetic factors.

Methodology/Principal Findings: We explore how self-reported risk taking in different domains correlates with variation in the dopamine receptor D4 gene (DRD4). Past studies conflict on the influence of DRD4 in relation to risk taking. A sample of 237 serious tournament contract bridge players, experts on risk taking in one domain, was genotyped for having a 7-repeat allele (7R+) or not (7R-) at DRD4. No difference was found between 7R+ and 7R- individuals in general risk taking or in several other risk-related activities.

Conclusion: In this sample of individuals (tournament bridge players) there is no relationship between DRD4 genotype and self-reported risk taking in different domains.

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Introduction

Recent research collaborations between economists and biologists, specifically geneticists and neuroscientists, attempt to explore the genetic components of economic decision making. Twin studies have pointed to a genetic component in behaviors such as risk taking [1-5], altruism in the dictator game [2], rejection behavior in the ultimatum game [6], trust behavior in the trust game [7], and behavioral biases [8]. A number of studies focus on the specific genetic loci involved in the genetic transmission of economic behaviors [9-14], with particular focus on risk preferences on monetary gambles [12,15-25].

This literature provides mixed evidence on whether genetic factors contribute to the often observed individual variation in economic behaviors. With respect to risk preferences, substantial attention has been given to the dopamine system, given its relation with reward processing in the brain. Activation of the dopaminergic reward pathways, and thus the release of dopamine neurotransmitters, gives rise to feelings of pleasure that in turn become linked to the behaviors that triggered the activation. Dopamine thus plays a substantial role in reinforcing behaviors that are associated with the anticipation of rewards.

The dopamine receptor D4 gene (DRD4) was identified early on as a potential candidate to explain some variation in economic behavior [26]. The DRD4 receptor gene is located on chromosome 11 and contains a 48 base pair variable number tandem repeat (VNTR) polymorphism that generally consists of 2-11 repeats [27]. The different alleles are frequently divided into dichotomous classes, 7R+ and 7R-, where those with 7 or more repeats on at least one chromosome are assigned to the 7R+ class and those with fewer than 7 repeats on both chromosomes are assigned to the 7R- class [27]. Functionally, individuals with the 7R+ genotype are putatively less sensitive to dopamine uptake, implying that they require higher dopamine levels to produce a response of similar magnitude to that of 7R- individuals. Stimulating behaviors will produce a response in the brain's corticomesolimbic dopamine reward pathway. This genetic variation in dopamine response may thus contribute to individual variation in personality and behaviors associated with the dopamine system.

There is some evidence that economic risk taking might be one of these domains, but the results thus far are inconclusive. A positive association between the 7R+ genotype and risk taking on monetary gambles has been found in three studies [12,16,17] However, the effect is only present among men and not women in one of the studies [12]. Two studies find no

association [22,24] but in one of these 7R+ men become more risk taking than 7R- men when they are administered the dopaminergic precursor drug L-dihydroxyphenyalanine (L-DOPA) [22]. Another study even finds evidence of a negative association (marginally significant) between economic risk taking and 7R+ in another study [23]. However, that same study finds that 7R+ individuals are found to be more risk taking than 7R- individuals when the probabilities are uncertain and when the task is framed in terms of losses rather than gains. More research in this field is clearly needed to clarify the relationship between genetic propensities and economic behavior.

This paper investigates the relationship between DRD4 and self-reported risk taking in several domains related to economic decision making. These domains involve general risk taking, smoking and alcohol habits, proportion of assets invested in stocks and bonds, and whether participants had ever started a company. We analyze only the single gene DRD4. Drawing from the literature, we hypothesize that 7R+ individuals will be more risk taking than 7R- individuals on all risk measures. As far as we know, only one previous study explores the relationship between 7R+ and self-reported economic decision making outside of the laboratory. Carpenter et al. (2011) [23] find that 7R+ individuals hold fewer funds in savings, are less likely to have overdraft protection on their checking accounts, less likely to pay their credit card balance each month, but more likely to pay their bills through automatic deduction procedures.

Our sample of participants has considerable experience with contextual risk taking, and are regularly engaged in risk taking situations. Our participants are serious tournament bridge players, and effective risk taking is a significant component of contract bridge expertise. Our participant pool is thus much more diverse than the typical undergraduate student participant pool in terms of age and background, though perhaps less diverse in terms of economic status. Our prior work with this same sample shows that 7R+ men, though not women, take greater risks in a monetary gamble. More intriguing, 7R+ men with greater skill (as indicated by masterpoint totals, a salient measure of accomplishment in contract bridge) are better risk takers in bridge, taking more good risks and fewer bad risks. However, skill does not affect risk taking among 7R- men [12].

Material and Methods

Ethics Statement

All participants gave written informed consent to participate in the experiment and provided us with a DNA sample. The study was approved by the Committee on the Use of Human Subjects at Harvard University. All genotyping procedures were additionally approved by Binghamton University's Human Subjects Research Review Committee.

Participants

237 serious tournament contract bridge players were recruited at the Fall 2008 North American Bridge Championship, held in Boston, Massachusetts. Tables for data collection were placed outside the major national championship game rooms one day and outside a secondary championship game room the following day.

Measures

Each participant first solved an incentivized bridge quiz that tested both their skill and risk taking propensity in bridge contexts, and then made a decision on a risky gamble involving real financial payoffs [12]. They then filled out a short questionnaire (see Appendix 1).

The questionnaire included a self-reported risk question used previously [28] that asked about the individual's willingness to take risks on an 11-point Likert scale: "Are you a person who is generally prepared to take risks or do you try to avoid taking risks?" In a sample of approximately 22,000 individuals, it was found that the answer to this self-report risk question was negatively correlated with age and female, and positively correlated with height and parental education. It was also found that in a representative sample of 450 individuals, this measure was strongly predictive of actual risk taking behaviors, such as traffic offenses, portfolio choice, smoking, occupational choice, participation in sports and migration. Other studies have also found that this self-report measure correlates with stock market participation [29,30].

Our questionnaire also included questions on gender, age (binned with options <20, 20-30, 30-40, 40-50, 50-60, 60-70, 70-80, 80-90, and 90+), smoking and alcohol habits, proportion of assets invested in stocks and bonds, and whether participants had ever started a company. Most of the variables are categorical. Logic, and past studies (e.g. [31-33]), would suggest that a number of these questions are related to risk preferences. For example, the

proportion of assets invested in stocks and in bonds relates to financial risk taking. In our analysis we disregard participants who answered "don't know" (corresponding to 10 participants for stocks and 2 participants for bonds). Participants were given intervals that they could choose among, in increments of 10%. If the participant chose the "less than 10%" category, it is coded as 0.05, "10-20%" is coded as 0.15, etc. The percentages invested add up to less than one, since there are other unspecified categories of investment. We assume that on average these unspecified investments are instruments that are less risky than stocks (such as money market funds or savings accounts), making the proportion of assets in stocks a positive indicator of risk taking. The effect on bonds is more ambiguous, since bonds are more risky than a savings account but less risky than stocks. For this reason we employ the variable stocks/(stocks+bonds) to measure risk taking in investments.

Similarly, we take whether the participant had ever started a company as a proxy of entrepreneurship, a positive risk indicator. Moreover, participants indicated how many cigarettes they smoke each month and how many alcoholic drinks they consume each month, both risk-related activities. More specifically, there is a large literature linking variation in DRD4 to various forms of sensation seeking and risky behavior (e.g., [34-37]. To analyze this, we create two dummy variables: each takes the value 0 if the answer is 0 to the specific question (i.e., never drink or smoke), and 1 otherwise.

Genotyping

Each participant was given a 15ml centrifuge tube containing approximately 10ml of Scope® mouthwash. Participants gently swirled the mouthwash from cheek to cheek for 45 seconds, to collect buccal cells. Using a sterile straw, participants were instructed to spit the sample back into the same centrifuge tube [38]. Samples were later centrifuged and prepared for DNA extraction using the Maxwell® 16 System (Promega). Genotyping was performed at the Laboratory of Evolutionary Anthropology and Health at Binghamton University, New York (see [16]).

Sufficient DNA for DRD4 PCR amplification was extracted from 86% (203/237) of the buccal cell samples. The PCR reaction was modified to reflect the high GC content (see below) and all samples that were initially scored as homozygotes were reanalyzed two additional times with different starting template concentrations to confirm genotypes. The PCR reaction consisted of 1x Q-Solution (Qiagen), 1x Buffer (Qiagen), 1 μM Primer 1 (5'

GCGACTACGTGGTCTACTCG 3'), 1 µM Primer 2 (5' AGGACCCTCATGGCCTTG 3'), 200 µM dATP, 200 µM dTTP, 200 µM dCTP, 100 µM dITP, 100 µM dGTP, 0.3 units HotStar Taq (Qiagen), and 1 µl of DNA template, in a total volume of 10 µl. The PCR profile began with 15 minutes at 95°C for enzyme activation and denaturing of template DNA followed by 40 cycles consisting of 1 minute denaturation at 94°C, 1 minute annealing at 55°C, 1.5 minute extension at 72°C, and finished with a 10 minute extension at 72°C. Amplicons were electrophoresed through 1.4–2.0% agarose gels containing ethidium bromide and genotypes were determined by comparison with a 100 bp ladder. Participants were then scored as either 7R+ (at least one allele of at least 7-repeats or more) or 7R- (both alleles less than 7-repeats).

Population stratification can be an issue in candidate gene studies such as the one we have performed (see [39]). If there are allele frequency similarities among subpopulations of homogenous ancestry, this could bias results. In our sample, an overwhelming majority of participants self-reported Caucasian race; thus we believe that these legitimate concerns are minimal in our particular study.

Statistical Analysis

When the dependent variable is continuous, we use linear regressions (OLS) with robust standard errors. When it is binary, we employ a logit regression with robust standard errors. We report two-tailed test statistics. We use a binary variable that takes the value 1 if an individual is 7R+ and 0 if an individual is 7R-. A few participants did not indicate their age or gender. These participants were excluded from all analyses in order to keep the sample size constant across regressions for a particular outcome variable.

Results

Variation in the DRD4 gene was successfully analyzed for 190 men and women of our 237 participants. An additional 13 individuals were analyzed who did not report their gender. As previously reported [12], 19 out of 105 men for whom DRD4 data was obtained were 7R+ (18.1%). Among the women, 6 out of 85 were 7R+ (7.1%). These two frequencies are significantly different (chi^2 test: p=0.025). This is a surprising irregularity and may suggest a selection bias into competitive bridge that differs between men and women. We examine a 7R+-by-gender interaction term in our analyses, and when this interaction is significant, we also analyze men and women separately.

7R+ and general risk taking

Given the positive effect of 7R+ in males on risk taking in a monetary gamble that we found in the same sample [12], we might expect 7R+ to also affect self-reported general risk taking. Indeed, risk taking on a monetary gamble was significantly positively correlated with general risk taking (r=0.276, p=0.0002). Nevertheless, looking at the whole sample, perhaps surprisingly, 7R+ has no significant effect when controlling for gender and age (p=0.714), nor when no controls are included (p=0.887). See Table 1. We also find no significant interaction effect between 7R+ and gender on general risk taking (p=0.918). Thus we do not look at the male and female samples separately. The only significant predictor of general risk taking is gender, where women report taking fewer risks (coeff=-1.19, p=0.001).

Table 1. General risk taking.

	(1)	(2)	(3)
7R+	0.081	-0.206	-0.178
	(0.14)	(0.37)	(0.25)
Age		-0.004	-0.005
		(0.03)	(0.04)
Gender (F=1, M=0)		-1.188	-1.177
		(3.34)**	(3.13)**
Gender X 7R+			-0.108
			(0.10)
Constant	6.300	6.890	6.888
	(34.30)**	(9.96)**	(9.91)**
Observations	176	176	176
R-squared	0.00	0.07	0.07
Robust t-statistics in parentheses			
* significant at 5% level; ** significant at 1% level			

7R+ and risky activities

To explore the potential effects of the 7R+ genotype on investment allocations, we look at our variable stocks/(stocks+bonds). In a regression analysis, we find no significant relationship between the 7R+ genotype and investment in stocks and bonds, either with covariates (p=0.528) or without them (p=0.839). See Table 2. Being female, however, is negatively associated with more risky investments (coeff=-0.112, p=0.001). The interaction effect between 7R+ and being female is not significant (p=0.190).

Table 2. Asset allocation to stocks/(stocks+bonds).

	(1)	(2)	(3)
7R+	-0.010	-0.029	-0.002
	(0.20)	(0.63)	(0.03)
Age		0.019	0.018
		(1.42)	(1.34)
Gender (F=1, M=0)		-0.112	-0.100
		(3.30)**	(2.77)**
Gender X 7R+			-0.126
			(1.32)
Constant	0.664	0.609	0.609
	(36.37)**	(8.03)**	(8.05)**
Observations	162	162	162
R-squared	0.00	0.06	0.07
Robust t-statistics in parentheses			
* significant at 5% level; ** significant at 1% level			

Exploring our entrepreneurship variable (whether participants have started a company or not) in a logit regression, this variable is not significantly correlated with 7R+ in the total sample, when controls are included (p=0.792) or not (p=0.960), nor is the interaction effect between 7R+ and being female (p=0.271). See Table 3.

Table 3. Entrepreneurship (having started a company or not).

	(1)	(2)	(3)
7R+	0.023	0.121	-0.198
	(0.05)	(0.26)	(0.38)
Age		0.210	0.217
		(1.75)	(1.81)
Gender (F=1, M=0)		0.009	-0.116
		(0.03)	(0.34)
Gender X 7R+			1.405
			(1.10)
Constant	0.488	-0.648	-0.623
	(3.02)**	(1.01)	(0.98)
Observations	187	187	187
Robust z statistics in parentheses			
* significant at 5%; ** significant at 1%			

For smoking and drinking alcohol, we perform logit regressions and find no significant relationship between 7R+ and smoking or drinking with control variables (p=0.278 resp. 0.831) or without control variables (p=0.175 resp. p=0.847). Focusing on the control variables, women are less likely to drink than men (coeff=-1.00, p=0.028). See Table 4. There are no smoking 7R+ women; thus we do not include an interaction variable between 7R+ and being female in the analysis of smokers. For alcohol, this interaction is not significant (p=0.714).

Table 4. Smoking (1-2) and drinking (3-5).

	(1)	(2)	(3)	(4)	(5)
7R+	-1.420	-1.154	0.113	-0.128	0.066
	(1.36)	(1.08)	(0.19)	(0.21)	(0.08)
Age		0.206		0.010	0.007
		(1.16)		(0.05)	(0.04)
Gender (F=1, M=0)		0.719		-0.996	-0.939
		(1.57)		(2.20)*	(1.97)*
Gender X 7R+					-0.451
					(0.37)
Constant	-1.716	-3.270	1.497	2.002	1.980
	(7.88)**	(3.20)**	(7.39)**	(2.24)*	(2.22)*
Observations	188	188	188	188	188
Robust z statistics in parentheses					
* significant at 5%; ** significant at 1%					

In sum, we found no evidence of a correlation between variation in the dopamine receptor gene DRD4 and the risk related activities explored in this study.

Discussion

This study explores the effects of variation in the dopamine receptor gene DRD4. This gene has previously been related to risk preferences in the economic domain, though with some inconsistent results [12,16,17,22-24]. Our analysis seeks to deepen the field's understanding of 7R+'s relationship to risk taking by looking at risk taking in different domains. However, we find no evidence of a relationship between 7R+ and these risk related behaviors.

In terms of explaining the lack of relationship between 7R+ and self-reported risk taking, it could perhaps be the case that 7R+ individuals don't realize that many of their behaviors are considered risky by others. This could explain the null result with general risk taking, but does not explain the lack of relationship with self-reported risk-related activities. Our

results are somewhat in line with those of [18], who find different genes correlating with economic and psychological risk measures. However, [23] find that 7R+ correlates with self-reported risk measures similar to the ones we used. Their sample mainly consists of students, whereas our sample consists of tournament contract bridge players who tend to be older, and perhaps also of higher economic status, which might explain some of this discrepancy. Our subject pool also seems to be somewhat atypical from a genetic perspective: The frequency of 7R+ alleles in our sample is rather low compared to what most previous studies on US populations have found, and there is a significant difference in 7R+ frequencies between men and women in our sample [12] (gender differences in 7R+ frequency are not usually observed). Thus different types of men and women may be attracted to tournament contract bridge, and bridge players of both genders may differ in important ways from the general public.

Interestingly, [28] found evidence for a single trait operating in the different risk contexts they explore, but with some variation across contexts, perhaps due to differences in risk perception. In their study, it is interesting to note, the general risk question effectively predicted all behaviors (including portfolio choice and smoking). Moreover, [28] had about 7% of their sample answer 0 (lowest risk taking) on this risk question, whereas in our sample no one answered 0. This could be due to a variety of factors. There could be more risk takers in our sample, or more familiarity in thinking about risk questions. It could also be a framing response: the individuals were in the midst of a bridge tournament, where risk taking is a prime ingredient. It is also interesting to note that [2], using the same general risk taking question in a twin study, find a genetic component (of about 35%), and that [15] find that it is related to the serotonin transporter 5HTTLPR; thus perhaps genes other than DRD4 are involved in that process. Moreover, the interaction effects of multiple behavioral neurogenetic loci likely contribute to complex genotype-phenotype relationships in individuals.

Our negative findings are surprising in light of the literature, and given that 7R+ for men in this same sample did correlate with risk taking on a monetary gamble. Perhaps part of the explanation is that as national bridge championship participants, these subjects were expert and experienced risk takers. Clearly the relationship among genes, skill and experience in risk taking is of sufficient importance and complexity to merit further investigation.

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Appendix 1

Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?

(Unwilling to take risks) 0 1 2 3 4 5 6 7 8 9 10 (Fully prepared to take risks)

Age (years):

<20	20-30	30-40	40-50	50-60	60-70
70-80	80-90	90+			

Gender/sex: Male Female

Over the last five years, approximately what proportion of your assets, apart from residence(s), have been invested in stocks?

Less than 10%	10-20%	20-30%	30-40%	40-50%	50-60%
60-70%	70-80%	80-90%	More than 90%	Don't Know	

Over the last five years, approximately what proportion of your assets, apart from residence(s), have been invested in bonds?

Less than 10%	10-20%	20-30%	30-40%	40-50%	50-60%
60-70%	70-80%	80-90%	More than 90%	Don't Know	

Have you ever started your own company?

Yes No

If you smoke cigarettes, on average how many packs of cigarettes do you smoke each month? (enter 0 if non-smoker)?

_____ packs

If you drink alcoholic beverages, on average how many alcoholic drinks do you have each month? (enter 0 if non-drinker)?

_____ drinks