Journal of the International Neuropsychological Society (2008), **14**, 1063–1068.

doi:10.1017/S1355617708081204

BRIEF COMMUNICATION

Education level moderates learning on two versions of the Iowa Gambling Task

CAROLINE DAVIS,[1] JOHN FOX,[2] KAREN PATTE,[1] CLAIRE CURTIS,[1] RACHEL STRIMAS,[1] CAROLINE REID,[1] AND CATHERINE McCOOL[1]

[1]Faculty of Health Sciences, York University, Toronto, Canada
[2]Department of Sociology, McMaster University, Hamilton, Ontario, Canada

(RECEIVED January 7, 2008; FINAL REVISION June 21, 2008; ACCEPTED June 23, 2008)

Abstract

The Iowa Gambling Task (IGT) is the major plank of behavioral support for the *Somatic Marker Hypothesis*—a prominent theory of emotionally-based decision making. Despite its widespread use, some have questioned the ecological and discriminative validity of the IGT because a substantial proportion of neurologically-normal adults display a response pattern indistinguishable from those with ventromedial prefrontal cortical brain lesions. In a large sample of healthy adults, we examined the statistical influence of several demographic variables on two versions of the IGT, with the specific prediction that educational attainment would moderate learning across trials. Results confirmed a highly significant effect of education. On the commonly used original version of the IGT, performance tended to improve more rapidly, and reach a higher eventual positive score, as the level of education increased. Age and gender were nonsignificant effects in the model, and Caucasians had slightly better IGT performance than their non-Caucasian counterparts. Conclusions are that education level, among neurologically-normal adults, should be treated as a stratification or matching variable in case-control research using this task. (*JINS*, 2008, *14*, 1063–1068.)

Keywords: Decision making, Neuropsychological tests, Reward, Behavior, Prefrontal cortex, Gender

INTRODUCTION

The neuroscientific research of Damasio and his colleagues has greatly advanced our understanding of why "intuition" seems to guide so many aspects of human behavior (e.g., Bechara et al., 2000; Damasio, 1994). The principal tenet of their popular theory of decision-making—known as the Somatic Marker Hypothesis (SMH)—is that our ability to choose *present* options, which favorably influence *future* outcomes, depends crucially on an accumulated "emotional memory" of the consequences of our *past* interactions with similar events. In other words, we form a probabilistic impression of how a particular action will turn out in the future from an emotionally-biasing "gut" feeling, or emotional imprint, which was generated when that action caused either a positive or a negative reaction in the past. The SMH has garnered considerable empirical support, especially from case-control studies of those with impairment in the neural circuitry involved in judgment and memory—viz. patients with bilateral damage to the ventromedial prefrontal cortex (VMPFC)—and those with substance dependence.

The Iowa Gambling Task (IGT) is a cleverly designed research tool (Bechara et al., 1994), which mimics the real-life contingencies required to choose advantageously in situations that involve either immediate or delayed rewards, and where the outcome of one's selection is probabilistic and uncertain. It is also the most frequently used neuropsychological measure of emotionally-based decision making, and the major plank of behavioral support for the SMH. While this task has strengths as an index of decision making, legitimate concerns have been raised about its *ecological validity*. For instance, most studies show that a substantial proportion of neurologically-normal (control) participants display a response pattern indistinguishable from patients with VMPFC lesions (see Dunn et al., 2006). On the one hand, this may simply mirror the natu-

Correspondence and reprint requests to: Caroline Davis, 343 Bethune College, York University, 4700 Keele Street, Toronto, ON, M3J 1P3, Canada. E-mail: cdavis@yorku.ca

ral human diversity that exists in prudent decision-making ability. On the other hand, it casts doubt on the discriminative utility of the IGT as an index of impairment, and argues for the identification of individual differences that influence IGT performance irrespective of, or in addition to, clinical classifications (Glicksohn et al., 2007).

While some IGT studies have reported demographic data such as age, gender, and education level, or controlled for their influence, few have examined the effects of these factors in a systematic way. Educational attainment is a particularly relevant variable because it is strongly linked to intelligence (e.g., Bacete & Remirez, 2001; Ganzach, 2000), and because both factors are positively associated with novel problem solving and effective decision making (see Rindermann, 2008). Of interest, Bechara and his colleagues have stated that performance on the IGT does not "seem to depend on education" (Bechara et al., 2000). More recently, Bechara (2007) published normative data for the IGT and reported that education had only a "minor" effect on IGT scores. What is still unclear, however, is whether, and if so how, education level affects *learning across trials* on the IGT. We suspect it will have a significant moderating effect for the reasons mentioned above.

To date, we are aware of only one study that has undertaken a formal investigation of the education-IGT link in healthy participants (Evans et al., 2004). These authors reasoned that university-level education should be *inversely* correlated with performance on the IGT. While their findings appear to support this claim, they are rather counterintuitive in our view. Additionally, the study is limited by a very small sample, and by the fact that all participants were under the age of 25 years. The latter is especially relevant because the human prefrontal cortex (the locus of "executive function") is still developing until adults are in their early to mid 20s (Gogtay et al., 2004). The 25-year participant age limit also restricts the range of possible educational attainment.

Other IGT studies, in a variety of contexts, have included education level as a secondary factor in their analyses. Collectively, the results have been inconclusive, and none has replicated the findings of Evans et al. (2004). For example, Fein et al. (2007) demonstrated a significant—albeit weak—*positive* relationship between years of education and IGT performance. However, the strength of this relationship was almost certainly attenuated by a restricted range in the education variable. A few other studies of nonrepresentative groups such as senior adults (Denburg et al., 2006) and alcoholics (Dom et al., 2006) have also found a positive association between education and IGT performance. By contrast, no effect of education level was found in other special groups such as those with substance-dependence (Verdejo-Garcia et al., 2006), suicide attempters (Jollant et al., 2007), and women with bulimia nervosa (Boeka & Lokken, 2006).

Over the past 3 years, we have obtained IGT and demographic information, including education level, age, gender, and race, from a large sample of healthy adult women and men on two different versions of the IGT. The data provide an excellent opportunity to examine statistically the simultaneous influence of these variables on IGT performance, and to test our specific hypothesis that education level moderates learning across trials.

METHODS

Participants

Adult women (n = 285) and men (n = 167) between the ages of 25 and 50 years were enrolled in the study. Participants were recruited from advertisements placed at public institutions and in local newspapers, asking for "healthy volunteers to take part in a personality psychology study." There was no difference in the mean age of the women (M_{age} = 34.31 years; SD = 7.33) and the men (M_{age} = 34.51 years; SD = 7.7). Seventy-two percent of the sample was Caucasian, and the racial distribution was not different between women and men (p = .378), nor among educational categories (p = .372). Given the high proportion of Caucasians in our sample, race will be treated as a dichotomous variable (Caucasians *vs*. non-Caucasians) in the subsequent data analyses.

As identified by a structured telephone screening before the testing appointment, participants were excluded if they had a serious medical condition or were being treated for any psychiatric condition including addiction disorders. This study was approved by the Human Research Ethics Board at the first author's institution.

Measures

Decision-Making was assessed by two computerized versions of the IGT. In the *original* task [IGT1] (Bechara et al., 1994), participants were asked to choose among four decks of cards, two (A′& B′) yielding high immediate gain, but larger future losses; and two (C′& D′) yielding lower immediate gain but smaller future losses. They were told that the goal of the game is to accumulate as much money as possible by picking one card at a time, and that to win money, they should know that some decks are better than others. Scores on both tasks are typically calculated in 5 blocks of 20 trials (see Bechara & Damasio, 2002), whereby the number of cards from the disadvantageous decks (A′& B′) are subtracted from the advantageous decks (C′& D′). Therefore, a positive score reflects a tendency to make good decisions. In the *variant* version of the task [IGT2], the contingencies are reversed—loss occurs on every trial while gain is delayed and intermittent (see Bechara et al., 2002). The advantageous decks (E′& G′) yield high immediate punishment, but higher future reward. The disadvantageous decks (F′& H′) yield low immediate punishment but lower future reward.

Education level

During a face-to-face interview, subjects were asked to report their highest level of education according to seven catego-

https://doi.org/10.1017/S1355617708081204 Published online by Cambridge University Press

ries: 1 = some high school; 2 = completion of high school; 3 = some technical college; 4 = technical college diploma; 5 = some university; 6 = university undergraduate degree; 7 = current postgraduate training or postgraduate degree.

Procedure

After giving informed consent, the demographic variables were obtained from each participant. Approximately half the participants completed the ABCD task first while the remainder did the tasks in reverse order. The verbal instructions given to participants before the start of each gambling task were from a standard script provided by Bechara and his colleagues. To increase the probability that participants would play the games seriously, they were told that their payment for participation in the study would "depend on their performance on the computer tasks." In fact, all participants were given the same cash payment at the end of the study.

Statistical Analyses

We used the lme4 package in R (an updated version of the software described in Pinheiro & Bates, 2000) to fit standard linear mixed-effects models to the data, assuming normally distributed errors and random effects. The traditional scoring of the gambling tasks results in a transformed proportion: 20 times the proportion of advantageous choices minus the proportion of disadvantageous choices. Tukey (1977, page 498) calls this kind of variable a "plurality," which, as a general matter, is not a favorable scale on which to analyze data by linear models. In this instance, the scores are negatively skewed, with approximately 13% of scores at the upper boundary of 20 and approximately 2% at the lower boundary of −20. We instead used the empirical logit (Cox & Snell, 1989, page 32) of advantageous choices, defined as the log of the number of advantageous choices plus one-half, divided by the number of disadvantageous choices plus one-half. This transformation does not entirely remove floor and ceiling effects, but it does make the distribution of the dependent variable much more symmetric. To display the results of our analysis, we apply the inverse-logit transformation, to express the results on the traditional −20 to 20 plurality scale. As it turns out, we obtained nearly identical results whether we analyzed the plurality or the empirical-logit of advantageous choices, but we prefer the latter for the reasons stated.

RESULTS

Table 1 presents the net score means and standard deviations for the five blocks of trials for the two IGTs.

Table 1. Means and standard deviations for IGT task 1 and task 2 listed by net block scores (i.e., good decks minus bad decks for each group of 20 trials)

IGT Task 1 (ABCD)		
Blocks of 20 trials: good decks minus bad decks	Mean	*SD*
Net 1	−2.7	8.6
Net 2	2.52	8.6
Net 3	4.2	9.9
Net 4	4.6	9.9
Net 5	5.5	10.4
IGT Task 2 (EFGH)		
Blocks of 20 trials: good decks minus bad decks	Mean	*SD*
Net 1	0.91	8.4
Net 2	5.0	11.4
Net 3	6.9	10.6
Net 4	6.1	10.4
Net 5	4.5	11.2

Table 2 displays the results of fitting several linear mixed-effects models to the data. In each case, we show the fixed and random effects, and the degrees of freedom for the model (i.e., its number parameters, including both fixed-effect coefficients and random-effect variance and co-variance components). The deviance for each model is twice the negative of the maximized log-likelihood under the model and is a building block (analogous to the residual sum of squares for a traditional fixed-effects linear model) for likelihood-ratio tests of terms in the model. To test both fixed-effect parameters and variance and covariance components by likelihood-ratio tests, we used full maximum-likelihood (ML), as opposed to restricted maximum-likelihood (REML). Estimates of fixed effects for our final model (model 11 in Table 2) are essentially identical for the ML and REML estimates.

Model 1 is the most complex that we fit to the data, including fixed main effects of the "demographic" control variables sex, race, and age, interactions among education, task, and trial blocks (represented as a fourth-order polynomial), and random effects representing the interaction between task and trial blocks (again as a fourth-order polynomial). Because there are five trial blocks, a fourth-order polynomial will capture any pattern of change over their course. We checked first whether we could simplify the trend over trial blocks, by a step-down test, representing blocks in the fixed and random parts of the model by a third-order polynomial, producing model 2. The likelihood ratio test contrasting models 1 and 2, given in the first line of the lower panel of Table 2, shows that the quartic term in highly significant. Models 3 through 6 allow us to test the fixed effects of sex, race, age (represented as a second-order polynomial, because age effects are often quadratic), and the three-way interactions among education, task, and trial blocks. These tests are given in the lower panel of Table 2.

The race effect is just significant at the 5% level, and the sex effect just nonsignificant. Neither the age effect nor the

https://doi.org/10.1017/S1355617708081204 Published online by Cambridge University Press

Table 2. Mixed-effect models fit to the data, and tests for terms in the models

Fixed Effect Models

Model	Fixed effects	Random effects	*df*	Deviance
1	Sex, race, age (quadratic), education × task × blocks (quartic)	task × blocks (quartic)	129	14673.56
2	Sex, race, age (quadratic), education × task × blocks (cubic)	task × blocks (cubic)	96	14743.47
3	Race, age (quadratic), education × task × blocks (quartic)	task × blocks (quartic)	128	14677.05
4	Sex, age (quadratic), education × task × blocks (quartic)	task × blocks (quartic)	128	14677.64
5	Sex, race, education × task × blocks (quartic)	task × blocks (quartic)	127	14676.05
6	Sex, race, age (quadratic), education × task, education × blocks (quartic), task × blocks (quartic)	task × blocks (quartic)	105	14695.90
7	Sex, race, age (quadratic), education × blocks (quartic), task × blocks (quartic)	task × blocks (quartic)	99	14701.66
8	Sex, race, age (quadratic), education × task, task × blocks (quartic)	task × blocks (quartic)	81	14746.08
9	Sex, race, age (quadratic), education × task, education × blocks (quartic)	task × blocks (quartic)	101	14719.85
10	Sex, race, age (quadratic), education × task × blocks (quartic)	task, blocks (quartic)	95	15347.00
11	Sex, race, education × blocks (quartic), task × blocks (quartic)	task × blocks (quartic)	97	14704.14

Test for Terms in the Models

Terms	Models contrasted	Likelihood-Ratio statistic	*df*	*p*
Blocks (quartic)	2-1	69.91	33	.0002
Sex	3-1	3.50	1	.061
Race	4-1	4.09	1	.043
Age (quadratic)	5-1	2.50	2	.29
Education × task × blocks (quartic)	6-1	22.34	24	.56
Education × task	7-6	5.76	6	.45
Education × blocks (quartic)	8-6	50.18	24	.0013
Task × blocks (quartic)	9-6	23.95	4	$<.0001$
Random: task × blocks (quartic)	10-1	673.45	34	$\ll.0001$
Omitted from final model	11-1	30.59	32	.54

interaction among education, task, and trial blocks proved to be statistically significant. Beginning with model 6 in Table 2, which eliminates the interaction among education, task, and trial blocks, we exclude each of the two-way interactions among these factors to test the corresponding fixed effects. Both the education-by-blocks and task-by-blocks interactions proved to be highly statistically significant, while the education-by-task interaction is not. Finally, contrasting models 10 and 1, we tested whether the variance and covariance components for the random effects of task by trial blocks are required—that is, whether there is significant inter-subject variation in trajectories. These variance and covariance components are highly statistically significant. Model 11 eliminates the nonsignificant terms, with the exception of the fixed effect of sex, which was nearly significant. As the last line of the lower panel in Table 2 indicates, this model provides a good fit to the data.

The substantive focus of our data analysis is on the interactions between education and task and between education and trial blocks. These are displayed in the "effect plot" in Figure 1, which is constructed using model 11 (see Fox, 1987). The dummy regressors for sex and race, which enter the model additively, are each set to 0.5, representing a group composed equally of males and females, and of Caucasians and non-Caucasians. Then education, task, and trial blocks are allowed to range over all combinations of their values, computing the fitted value of the advantageous minus disadvantageous choices within each such combination; these fitted values are represented by the dots in the graph, connected by solid lines. Finally, the broken lines indicate plus-and-minus one standard error around the fit, and thus represent approximate point-wise 68% confidence intervals for the fitted values.

DISCUSSION

Our results demonstrated that *learning* on the IGT (as indicated by trial block scores) was moderated both by the type of task and by education level. Notably, however, we did not find a 3-way interaction among these variables. Nor was there a significant 2-way interaction between education and task. As seen in Figure 1, subjects' performance tended to improve more rapidly, and reach a higher eventual positive score, as the level of education increased. For task 1, the increase was roughly linear. On task 2, there was a tendency for performance to rise initially and then to decline—a pattern that was consistent even at higher levels of education. The task 2 results are particularly puzzling.

https://doi.org/10.1017/S1355617708081204 Published online by Cambridge University Press

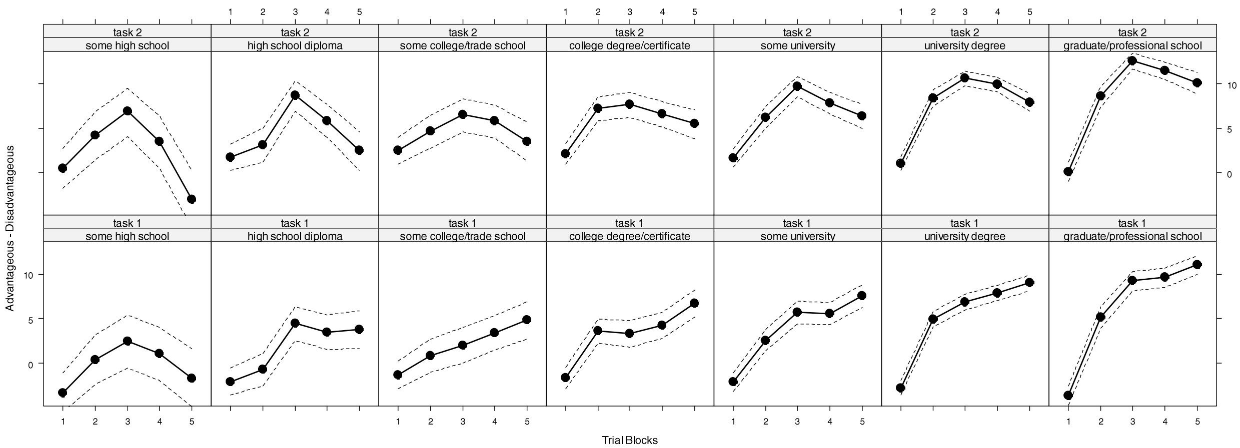

Fig. 1. Fitted number of advantageous minus disadvantageous choices as a function of task, education, and trial blocks. The broken lines give plus and minus one standard error around the fits.

Unfortunately, comparison with other data is not possible because this version of the IGT has been included in so little research. One possible explanation, given the higher mean scores on the first four blocks of task 2 compared with task 1, is that some subjects ran out of cards from the "good decks" and had to resort to choices from the "bad decks" near the end of the game.[1]

The absence of a significant 3-way interaction in the analysis provides us with a replication of the IGT-education link in both tasks, and strengthens our confidence in the reliability of the findings. However, the causal direction of this relationship is unclear. For instance, there is evidence that both innate intelligence and accrued knowledge contribute to rational decision making and improved problem solving (see Rindermann, 2008). Consequently, there may be cognitive skills that improve with schooling and thereby aid in IGT performance. On the other hand, it is also reasonable to presume that some causally-prior variable(s) contributes both to good IGT performance and to educational attainment. One possibility is that the cognitive ability required to make rational decisions, to accurately assess risks, and to demonstrate appropriate precaution—basic tenets of the SMH—is a dimensional, largely biologically-based, human trait that influences the degree of one's success in many aspects of life. Relevant, for example, is the finding that 53% of homeless people had suffered a traumatic brain injury, and of these, 72% had their first episode before the onset of homelessness (Hwang et al., 2007). Such results raise the distinct possibility that their injury may have caused cognitive difficulties that contributed to their poor life success.

Similar to Bechara (2007), we found nonsignificant effects for age and gender. There was, however, a main effect for race indicating that Caucasians had slightly better IGT performance that their non-Caucasian counterparts. Interpretation of racial effects is very difficult in a multi-racial society because race is correlated with other potentially influential factors such as immigration status, economic status, and type of education.

Our study has several strengths including the large sample of fully adult participants, and the inclusion of several demographic variables in our analyses. The use of a categorical education-level variable also has some advantages because the more commonly used years-of-schooling typically has nonlinear and indeed discontinuous effects. For example, the difference between 11th grade and 12th grade is more important for income than the difference between 10th and 11th grade. On the other hand, a limitation of our study is the uneven frequency of observations in each of the education categories. Because the subjects in our study are relatively highly educated, we are able to estimate effects more precisely at higher levels of education, and this is reflected, for example, in the standard errors displayed in Figure 1. Nevertheless, we are able to demonstrate a statistically reliable and interpretable interaction between level of education and subjects' trajectories over trial blocks.

In summary, our results challenge the claim by Bechara (2007) that education has only a "minor" influence on IGT performance; instead our data demonstrate a pronounced and systematic influence on the pattern of learning across trial blocks on two versions of the IGT. As such, it would behoove future researchers to stratify samples according to education level when the IGT is used in clinical case-control research paradigms, or to match cases and controls on this and other variables. However, it is also important to recognize that matching on *quantity* of formal education does not equate *quality* of education. There is good evidence, for example, that different educational experiences foster differences in problem-solving strategies, knowledge, and opportunities for practice—all of which can influence test performance (Manly & Echemendia, 2007).

[1]There are only 60 cards in each deck so some subjects deplete a particular deck before the game is finished. It is not clear why this might have occurred more frequently on task 2 than on task 1.

https://doi.org/10.1017/S1355617708081204 Published online by Cambridge University Press

It will also be of interest for future researchers to untangle more clearly the complex nature of the relationship between IGT performance and education level. Does one acquire particular skills from higher education that foster better IGT performance, or is there a set of traits that predisposes one to make probabilistically advantageous choices in real-life as in neuropsychological tests like the IGT? Finally, if there are predisposing factors that influence cognitive development and subsequent test performance, to what degree are these innate, or developed through early (preschool) educational experiences and learning opportunities in the home (see Byrd et al., 2006)?

ACKNOWLEDGMENT

This research was funded by a grant to the first author (2005–2008) from the Social Sciences and Humanities Research Council of Canada (# 410-2005-2076).

REFERENCES

Bacete, F.J.G. & Remirez, J.R. (2001). Family and personal correlates of academic achievement. *Psychological Reports*, *88*, 533–547.

Bechara, A. (2007). *Iowa Gambling Task Professional Manual*. Lutz, FL: Psychological Assessment Resources, Inc.

Bechara, A. & Damasio, H. (2002). Decision-making and addiction: I. Impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia*, *40*, 1675–1689.

Bechara, A., Damasio, A.R., Damasio, H., & Anderson, S.W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*, 7–15.

Bechara, A., Damasio, H., & Damasio, A.R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex*, *10*, 295–307.

Bechara, A., Dolan, S., & Hindes, A. (2002). Decision-making and addiction: II. Myopia for the future or hypersensitivity to reward? *Neuropsychologia*, *40*, 1690–1705.

Boeka, A.G. & Lokken, K.L. (2006). The Iowa gambling task as a measure of decision making in women with bulimia nervosa. *Journal of International Neuropsychological Society*, *12*, 741–745.

Byrd, D.A., Miller, S.W., Reilly, J., Weber, S., Wall, T.L., & Heaton, R.K. (2006). Early environmental factors, ethnicity, and adult cognitive test performance. *The Clinical Neuropsychologist*, *20*, 243–260.

Cox, D.R. & Snell, E.J. (1989). *Analysis of Binary Data, Second Edition*. New York: Chapman & Hall.

Damasio, A.R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain*. New York: Grosset/Putnam.

Denburg, N.L., Recknor, E.C., Bechara, A., & Tranel, D. (2006). Psychophysiological anticipation of positive outcomes promotes advantageous decision-making in normal older persons. *International Journal of Psychophysiology*, *61*, 19–25.

Dom, G., De Wilde, B., Hulstijn, W., van den Brink, W., & Sabbe, B. (2006). Decision-making deficits in alcohol-dependent patients with and without comorbid personality disorder. *Alcoholism: Clinical and Experimental Research*, *30*, 1670–1677.

Dunn, B.D., Dalgleish, T., & Lawrence, A.D. (2006). The somatic marker hypothesis: A critical evaluation. *Neuroscience and Biobehavioral Reviews*, *30*, 239–271.

Evans, C.E.Y., Kemish, K., & Turnbull, O.H. (2004). Paradoxical effects of education on the Iowa Gambling Task. *Brain and Cognition*, *54*, 240–244.

Fein, G., McGillivray, S., & Finn, P. (2007). Older adults make less advantageous decisions than younger adults: Cognitive and psychological correlates. *Journal of the International Neuropsychological Society*, *13*, 480–489.

Fox, J. (1987). Effect displays for generalized linear models. *Sociological Methodology*, *17*, 347–361.

Ganzach, Y. (2000). Parents' education, cognitive ability, educational expectations and educational attainment: Interactive effects. *British Journal of Educational Psychology*, *70*, 419–441.

Glicksohn, J., Naor-Ziv, R., & Leshem, R. (2007). Impulsive decision-making: Learning to gamble wisely? *Cognition*, *105*, 195–205.

Gogtay, N., Giedd, J.N., Lusk, L., Hayashi, K.M., Greenstein, D., Vaituzis, A.C., Nugent, T.F., III, Herman, D.H., Clasen, L.S., Toga, A.W., Rapoport, J.L., & Thompson, P.M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences, United States of America*, *101*, 8174–8179.

Hwang, S.W., Colantonio, A., Chiu, S., Tolomiczenko, G., Kiss, A., Cowan, L., Redelmeier, D., & Levinson, W. (2007). Traumatic brain injury among homeless people. Presentation at the Annual Meeting of the American Public Health Association. November, Washington, DC.

Jollant, F., Buresi, C., Guillaume, S., Jaussent, I., Bellivier, F., Leboyer, M., Castelnau, D., Malafosse, A., & Courtet, P. (2007). The influence of four serotonin-related genes on decision-making in suicide attempters. *American Journal of Medical Genetics. Part B, Neuropsychiatric Genetics*, *144*, 615–624.

Manly, J.J. & Echemendia, R.J. (2007). Race-specific norms: Using the model of hypertension to understand issues of race, culture, and education in neuropsychology. *Archives of Clinical Neuropsychology*, *22*, 319–325.

Pinheiro, J.C. & Bates, D.M. (2000). *Mixed-Effects Models in S and S-Plus*. New York: Springer.

Rindermann, H. (2008). Relevance of education and intelligence at the national level for the economic welfare of people. *Intelligence*, *36*, 127–142.

Tukey, J.W. (1977). *Exploratory Data Analysis*. Reading, MA: Addison-Wesley.

Verdejo-Garcia, A., Vilar-Lopez, R., Perez-Garcia, M., Podell, K., & Goldberg, E. (2006). Altered adaptive but not veridical decision-making in substance dependent individuals. *Journal of the International Neuropsychological Society*, *12*, 90–99.