Fluid Intelligence and Psychosocial Outcome: From Logical Problem Solving to Social Adaptation

David Huepe5*, María Roca4, Natalia Salas1,2, Andrés Canales-Johnson5, Álvaro A. Rivera-Rei5, Leandro Zamorano3, Aimée Concepción1, Facundo Manes4, Agustín Ibañez4,5,6

1 Cognitive Development Center, Universidad Diego Portales, Santiago, Chile, 2 Faculty of Education, Universidad Diego Portales, Santiago, Chile, 3 Doctoral Program in Education, Pontificia Universidad Católica de Chile, Santiago, Chile, 4 Laboratory of Experimental Psychology and Neuroscience (LPEN), Institute of Cognitive Neurology (INECO) and Institute of Neuroscience, Favaloro University, Buenos Aires, Argentina, 5 Laboratory of Cognitive and Social Neuroscience, Universidad Diego Portales, Santiago, Chile, 6 National Scientific and Technical Research Council (CONICET), Buenos Aires, Argentina

Abstract

Background: While fluid intelligence has proved to be central to executive functioning, logical reasoning and other frontal functions, the role of this ability in psychosocial adaptation has not been well characterized.

Methodology/Principal Findings: A random-probabilistic sample of 2370 secondary school students completed measures of fluid intelligence (Raven’s Progressive Matrices, RPM) and several measures of psychological adaptation: bullying (Delaware Bullying Questionnaire), domestic abuse of adolescents (Conflict Tactic Scale), drug intake (ONUDD), self-esteem (Rosenberg’s Self Esteem Scale) and the Perceived Mental Health Scale (Spanish adaptation). Lower fluid intelligence scores were associated with physical violence, both in the role of victim and victimizer. Drug intake, especially cannabis, cocaine and inhalants and lower self-esteem were also associated with lower fluid intelligence. Finally, scores on the perceived mental health assessment were better when fluid intelligence scores were higher.

Conclusions/Significance: Our results show evidence of a strong association between psychosocial adaptation and fluid intelligence, suggesting that the latter is not only central to executive functioning but also forms part of a more general capacity for adaptation to social contexts.

Introduction

Fluid intelligence has been defined as the ability to think logically and solve problems in novel situations, independent of acquired knowledge [1]. Fluid intelligence reflects an individual’s capacity for abstract thought and reasoning and it contrasts with so-called “crystallized intelligence” [2], which depends on previous knowledge and educational achievement. Undoubtedly, fluid intelligence is relevant to the process of analyzing novel problems, identifying patterns and relationships that underpin these problems and using logical extrapolation. Several tests have been proposed to measure this important function; the Raven Progressive Matrices (RPM) is the most widely-used task [3]. RPM is a psychometric non-verbal multiple choice test that evaluates the global index of intelligence. This index is traditionally inferred from a general factor of the underlying intelligence quotient [IQ] known as the g factor [3]. Although the RPM presents some caveats related to the fact that it is an extended and general measure, i.e., different processes seem to influence the RPM score, specifically, perceptual processing and analytic or analogical reasoning [4], those criticisms are expected for any general static cognitive measure. In fact, RPM is the most widely-used measure of g [5]. The g factor is thought to directly reflect a broad factor underlying several cognitive functions, such as observation and reasoning and, in this sense, evaluates a general intellectual capacity [6]. Usually, this measure is employed to evaluate perceptive skills and is recommended as a standard assessment in school populations [6]. During the application of the RPM, participants identify relevant information based on their perception of the spatial organization of an array of objects and their task consists of filling in the missing piece of a set of patterns. (See the Measures section for more details.)

Neuroanatomically, fluid intelligence has been related to frontal functioning [7]. Frontal lobe lesions have been found to affect performance on tests of fluid intelligence [7–9] and functional imaging studies that measure g have shown increased extensive activity in the frontal area of the brain [10–13].

Alongside the view that the frontal lobe constitutes the neural basis of fluid intelligence, frontal lobe functioning has also been linked to executive functioning and complex social behavior. Support for this comes from several lesion studies, which show that frontal lobe damage can alter behavior and social adaptation [14–22].

The relationship between fluid intelligence, novel problem solving and executive dysfunction has been extensively studied...
The term “psychosocial adaptation” refers to the quality of life in terms of social activities and relationships, sense of control and self-image. It includes multiple dimensions, such as social behavior, emotional regulation and the development of habits [31]. Given these characteristics, any approach that would be appropriate for assessing psychosocial adaptation would need to be both socially focused and broad enough to be able to capture an individual’s subjective experience in several social domains, such as bullying, self-esteem, mental health and drug intake, among others.

Five social domains are particularly important for psychosocial adaptation: abuse of children and adolescents [32–36], bullying [37–41], drug use [32,42–49], self-esteem [50–52] and mental health problems [50–58]. Moreover, the experience of abuse and bullying are positively associated with substance use and depression in children and adolescents [40,59–63] as well as with negative effects on self-esteem [64–67]. To our knowledge, the relationship between said domains and fluid intelligence has not yet been studied.

Psychosocial adaptation is diagnosed and prognostically connected to neurological diseases [68], brain injury [69], aging, dementia and old age psychiatry [70–72], mental illness [73–76], ADHD and child/adolescent psychiatry [77–81], bipolar disorder and depression [82], schizophrenia [83–86] and epilepsy [87–88], to cite some examples. Neuropsychological and neurological assessments dominate the current neuropsychological and neuropsychiatric literature, but psychosocial considerations, in both the normal and the psychiatric/neurological population, are important. Psychosocial functioning represents an ecological evaluation of everyday adaptation and cognition, interlinked with cognition and emotion [89].

To our knowledge, no study with a large sample size, i.e., a random-probabilistic sample, has previously assessed the relationship between fluid intelligence and multiple measures of psychosocial adaptation. In the present study, we aimed to analyze this relationship by recruiting 2370 participants (controlled for educational level) who were tested on fluid intelligence using Raven’s Progressive Matrices (RPM) and psychosocial outcomes, including measures of child abuse antecedents, bullying, self-esteem, mental health and drug use. In brief, we found that the lower the RPM scores were, the lower the level of psychosocial adaptation. Our results provide evidence of a strong association between fluid intelligence and psychosocial adaptation, suggesting that fluid intelligence is not only related to executive functions but is also a central component of the ability to adapt to social contexts.

Materials and Methods

Participants

This study was part of a Chilean regional county survey conducted during 2010 and designed to evaluate the psychosocial factors associated with academic achievement in scholars from socially vulnerable contexts. Only students belonging to public schools of Santiago de Chile were evaluated and all of the county’s 21 public schools were included. Participants were recruited from primary schools, in the UK system, preparatory school covering the ages of 11–14 years old. From a total of 21 schools, 2370 students (age = 11.9 years, S.D. = 1.33; Sex = 46.8% female) were recruited using a random-probabilistic sample (maximum variance of 95% confidence with ±5% sample error). The students’ ages ranged from 10–14 years, with the majority in the range of 11–13 years (Table 1). The participants came from socially vulnerable contexts. As expected for this population, the parents of the participants presented lower educational levels (75% completed only primary or secondary studies, without technical or university instruction). All schools that participated in this study approved the research. All participants and their parents or legal guardians gave signed, voluntary consent following the Declaration of Helsinki. This study was approved by the ethics committee of the Universidad Diego Portales – Santiago de Chile.

Measures

Fluid intelligence. The Standard Progressive Matrices version of the RPM was used as a measure of general intelligence, or g factor [3]. We used a standardized version for the sample under assessment [6]. The RPM included 60 spatial tasks divided into five blocks of 12 trials, from easiest to hardest. In each trial, participants were asked to complete a series of drawings by identifying the relevant features based on the spatial organization of an array of objects and choosing one object that matched one or more of the identified features.

Psychosocial adaptation. To assess bullying behavior, the Delaware Bullying Questionnaire [90] was used, which included two sub-scales of violent behavior. One sub-scale assessed the respondent as victimizer (z = .73); it contained questions such as “Within this year, how often have you done these kind of things at school?,” “been part of a group that mocked a classmate who was alone”, “been part of a group that started a fight with another group”, “been part of a group that attacked members of another group”, “been part of a group that physically attacked a classmate who is alone”, among others. Another sub-scale assessed the respondent as victim (z = .72). It contained questions such as “have you been molested, while alone, by a group from your school?”, “have you been physically attacked, while alone, by a group from your school?”, “have you been in a group that has been attacked by another group?”, among others. Answer options included “never”, “once”, “twice”, “three or four times” and “five times or more”. Both scales measured the event using the following options: it did not happen (1); it happened once during the year (2); it happened more than once during the year (3).

Domestic abuse of adolescents was assessed using the Conflict Tactic Scale (CTS) [91]. The subscales of psychological violence (z = .80) contained statements such as “has stopped talking to you for several days”; “has told you he/she didn’t love you”; “has mocked you in front of other people”, among others. The questions assessing moderate physical violence (z = .84) included, among others, “has thrown things at you”; “has pulled your hair or ears”; “has pushed or shaken you”. Intense physical violence (z = .89) was assessed using statements such as “has given you a...
beating”; “has kicked, bitten or has given you a punch”; “has burned you with something (cigar, iron or hot water)”. The time scale included the following response options: “every day or almost every day”; “more than twice a week”; “more than twice a month”; “less than twice a month”; “has not happened in the last year, but it happened as a child” and “never”. Then, monthly and annual prevalence were calculated.

To assess drug intake, we used an international standardized scale [46] that evaluated monthly and annual prevalence of drug intake, specifically cannabis, cocaine, inhalants and non-prescribed stimulants (methylphenidate and methamphetamine).

Self-esteem was assessed using the Rosenberg’s Self-Esteem Scale (x^2 = .86) [92]. This scale includes statements such as “In general, I am happy with myself”; “Sometimes I feel like I am good at nothing”; “I feel like I have some good qualities”. Each item was measured on a scale ranging from “totally agree”, “agree”, “disagree”, to “totally disagree”. Rosenberg’s Self-Esteem Scale ranks respondents on a scale between 0 (low self-esteem) and 20 (high self-esteem).

Mental health problems were assessed using a Spanish adaptation of the Perceived Mental Health Scale [93]. The Perceived Mental Health Scale includes questions such as “In the last four weeks, have you felt sad?”; “In the last four weeks, have you had attitude problems at school?”; “In the last four weeks, have you felt tired all the time?” The Mental Health Scale ranks respondents on a scale between 0 (no mental health problems) and 20 (maximum mental health problems).

Procedure. The assessments were performed by a team of trained social psychologists (n = 4) in each educational institution. In order to avoid cheating, the students were divided into two to four classrooms and the overall process of RPM and psychosocial application was carefully supervised by the team of psychologists. The average duration of the assessment was 29 minutes (S.D. = 9.0) for the RPM and around 20 minutes for the psychosocial measures. There was a deadline of 45 minutes for the RPM and 30 for the psychosocial scale assessment. Only participants who finished all assessments within the time interval provided were included in the current study. Assessments were carried out at twenty-one institutions over a period of one month. The children’s parents were notified about the procedure by the authorities of the educational institutions.

Statistical Analysis. The data were analyzed using SPSS software (Statistical Package for the Social Sciences, version 17.0). To assess the association between RPM scores and each measure of violence, correspondence analysis (CA) was used [94]. CA is a descriptive measure to represent contingency tables, i.e., tables in which the frequency of two or more qualitative variables are collected from a group of elements. CA allows the representation of the interdependence among variables measured using a nominal scale. This technique transforms non-metric data (ordinal and categorical variables) into metric data, allowing one-dimensional reduction (as a factorial analysis) and perceptual mapping (as a multidimensional analysis). In addition, ANOVA and χ^2 were used as tests of independence. For the χ^2 correlations, Cramer’s V was computed. Cramer’s V ranges between 0 and 1 to indicate the strength of association between two variables. For pairwise comparisons, Tukey’s HSD post hoc tests were performed. To determine the relevance of the relationships, measures of the effect size w (for proportions) and d (for mean differences) were calculated [95]. The calculation of effect sizes allows the assessment of the magnitude of relationships beyond the mere reporting of p-values, which only specify the existence of statistically significant relationships. The calculation of effect sizes should temper the concerns about finding significant results solely on the basis of a large sample size and help avoid treating every significant result equally. To control for confounding variables, logistic regressions were run between the RPM and the binary variables, including parental educational levels, as predictors. ANCOVA was used to achieve the same control in evaluating the relationship between RPM and our measures of mental health and self-esteem.

Results

RPM scores

Five levels of scoring for the RPM were constructed in order to relate fluid intelligence to psychosocial adaptation. The total RPM index for each of the percentiles 5, 10, 25, 50, 75, 90 and 95 for each age group were obtained. Based on those indexes five scores were obtained (Table 2).

RPM and Bullying

The Delaware Bullying Questionnaire showed that 1 out of 3 (30.3%) students reported having exhibited violent behavior in the last year; 18.2% of the participants reported more than two episodes of violent behavior against other students and 51.5% reported that they had never performed a physical assault on another student. When the relationship between these results and the RPM scores was analyzed, the CA revealed a significant effect (χ^2 (8, N = 3692) = 109.62, p < .001). To facilitate the interpretation of these data and following technical suggestions [92], table 3 shows the χ^2 distances between the categories of each variable.

Reduced or absent bullying behavior was associated with higher RPM scores. On the contrary, repetitive bullying behavior was related to lower RPM scores. The bi-space diagram shows the association between RPM scores and bullying behavior (Figure 1).

Regarding victimization, similarly to the victimizer scales, 1 out of 3 (30.1%) students reported having been exposed to violent behavior in the last year; 16% of the participants were exposed to more than two episodes of violent behavior against them; 52% reported to have never been exposed to physical assault from other students. When the relationship between victimization and RPM scores was analyzed, the CA revealed a significant effect (χ^2 (6, N = 3704) = 67.03, p < .001). As before, Table 4 shows the χ^2 distances between the categories of each variable and Figure 1 the bi-spatial diagram. Similar to the results of the victimizer scale, a high correspondence was observed between reports of being a victim of violence more than once a year and lower RPM scores. At the

| Table 2. RPM’s five level score relating fluid intelligence with psychosocial adaptation. |
| --- |
| **Score** | **Level of intelligence** | **Percentile** |
| 1 | High superior | ≥95 |
| 2 | Moderate superior | ≥75 and <95 |
| 3 | Average | >25 and <75 |
| 4 | Moderate inferior | ≥5 and ≤25 |
| 5 | Low inferior | ≤5 |

The scoring was based on previous standardized studies reported in Chile in a sample of 4258 students (Ivanovic et al. [6]). Using this parameter a relatively normal participant distribution was observed in our five score levels: Score 1: 5.3%; Score 2:19.4%; Score 3: 48.2%; Score 4:19.9; Score 5: 7.2%. doi:10.1371/journal.pone.0024858.0002
same time, higher RPM scores seemed to be a protective factor against other’s aggression.

**RPM and drug intake**

Cannabis consumption showed an annual prevalence of 3%, followed by coca paste (2.2%) and cocaine (2%). The annual prevalence of use of all cocaine-related drugs, i.e., cocaine, coca paste and crack, was 3.3%; followed by inhalants (2.7%) and non-prescribed stimulants (2.2%). The composite score of drug intake presented an annual prevalence of 5.5%. This composite measure of drug consumption showed a significant association with RPM scores ($\chi^2 (4, N=3734) = 36.48$, $p<.001$, $V=.10$) and a medium effect size (Cohen’s $w=.42$). Lower scores of RPM were associated with higher percentages of drug use. Figure 2a shows the percentages for each RPM score.

**RPM and abuse of adolescents**

The adolescent abuse scale showed a high annual prevalence of within-family psychological violence: 52.5%, 1 out of 2 participants had been a victim of family violence. The annual prevalence of moderate physical violence was 40.2% and the prevalence of intense physical violence was 21.4%. RPM scores were highly associated with the annual prevalence of moderate physical violence ($\chi^2 (4, N=3735) = 12.80$, $p = .012$, $V = .06$, Cohen’s $w = .07$ small effect size) and intense physical violence ($\chi^2 (4, N=3735) = 25.50$, $p<.001$, $V = .08$; Cohen’s $w = .16$, small effect size; see Figure 2b). Nevertheless, no association between psychological violence and RPM scores ($4, N=3735) = 4.48$, $p = 0.35$, $ns$) was found.

**RPM and self-esteem**

The self-esteem scale yielded an average score of 21.25 ($S.D. = 5.74$; range between 0-lower and 30-higher). A one-way ANOVA with the 5 RPM scores as a within-subjects factor revealed a strong effect ($F(4, 3711) = 30.75$, $p<.001$). Post hoc comparisons (Tukey’s HSD test) show that in participants with lower RPM scores, lower reports of self-esteem were observed (Figure 2c). All post hoc comparisons were statistically significant at $p<.001$, except score 1 vs. score 2 and score 4 vs. score 5, which were not significant. The effect sizes of significant comparisons ranged from small to large (Cohen’s $d$ range = .20 to .77).

**RPM and perceived mental health**

The average total score for mental health-related problems reported was 6.88 ($S.D. = 4.76$; range between 0-lower and 20-higher). A one-way ANOVA with the 5 RPM scores as a within-subjects factor yielded a significant effect ($F(4, 3699) = 8.67$, $p<.001$). Similar to the results for the self-esteem measures, an inverse linear-like relationship was observed: the lower the RPM score, the higher the number of health problems reported (Figure 2d). Except for the pairwise comparison between scores 1–2, score 3–4 and score 4–5, which were not significant, the effect sizes of significant comparisons ranged from small to large (Cohen’s $d$ range = .20 to .77).

**Table 3. RPM Scores associated to the bullying victimizer categories ($\chi^2$ distances).**

| Score 1 | Score 2 | Score 3 | Score 4 | Score 5 |
|---------|---------|---------|---------|---------|
| Never   | 5.25    | 8.58    | 1.72    | –18.98  | –9.60   |
| Once in a year | –3.47   | –1.16   | –0.27   | 4.80    | 1.35    |
| Twice or more during the year | –2.22   | –12.96  | –2.45   | 21.09   | 14.31   |

Positive and higher values of $\chi^2$ distances are indicative of a strong association. Negative score are indicative of a lack of association.

**Table 4. RPM Scores associated to the bullying victim categories ($\chi^2$ distances).**

| Score 1 | Score 2 | Score 3 | Score 4 | Score 5 |
|---------|---------|---------|---------|---------|
| Never   | 2.02    | 4.11    | 0.43    | –3.72   | –9.85   |
| Once in a year | –0.00   | –1.03   | 0.01    | 0.03    | 1.39    |
| Twice or more during the year | –6.36   | –5.27   | –1.85   | 10.93   | 16.89   |

Positive and higher values of $\chi^2$ distances are indicative of a strong association. Negative score are indicative of a lack of association.

doi:10.1371/journal.pone.0024858.t003

doi:10.1371/journal.pone.0024858.t004

![Figure 1. Bi-spatial diagram showing the relation between bullying behavior and SMP score (victimizer and victim).](image-url) Circles display groups of categories close together.

doi:10.1371/journal.pone.0024858.g001
significant, all other comparisons yielded significant effects (Tukey’s HSD Test, \(p < .001\)). The effect sizes of the significant comparisons were small (Cohen’s \(d\) range = .14 to .36).

RPM effects controlling for parental education

As noted above, we controlled for two possible effects that could weaken or even cancel out our results: socioeconomic status and parental educational level. The first was fixed within the design because all of the population came from the same socioeconomic group and had a socioeconomic status of middle-low and lower. Despite this, the intelligence scores varied and showed a normal distribution, independent of socioeconomic status, which in this study was a constant. Therefore, the effects can be seen as being independent of this condition. Parental educational level was measured in terms of years of study (0 to 8 points) and was covaried with each of the relationships that were tested above. For the association between the RPM score and the measurement of bullying as the perpetrator, “Bully”, a logistic regression was used, with the following predictors: RPM score, father’s educational level and mother’s educational level. ‘Bully’ was coded as a dependent variable as 0 = Never, with a prevalence of 48.5% and 1 = Once a year or twice or more during the year, with a prevalence of 51.5%). RPM had an important effect in the expected direction (low RPM score – lower IQ – greater chance to trigger bullying, Table 5). We also found a similar outcome with ‘Bullied’ as the dependent variable. (This was coded 0 = Never, with a prevalence of 52% and 1 = Once a year or twice or more during the year, with a prevalence of 48%). RPM had an important effect in the expected direction (low RPM score – lower IQ – greater chance to trigger bullying, Table 5). We also found a similar outcome with ‘Bullied’ as the dependent variable. (This was coded 0 = Never, with a prevalence of 52% and 1 = Once a year or twice or more during the year, with a prevalence of 48%). In the case of “Bullied” only RPM was statistically significant in the predicted direction (Table 5). A similar finding was observed for the variable “use of illicit drugs”, annual prevalence (0 = Never, 1 = Yes, Table 5); and “intense physical violence” (Table 5). For “moderate physical violence”, all effects were significant (Table 5). However, the most relevant outcome is that the RPM effects described...
remain significant over and above the influence of the parental educational levels. Finally, for the associations between RPM with self-esteem and perceived mental health, we used ANCOVAs. In both cases, the effects found for RPM were retained. For self-esteem $F(4, 3531) = 28.59, p < .001$. The effects of the parental educational levels were not significant. For mental health, $F(4, 3520) = 8.91, p < .001$. Again, the effects of the parental educational levels were not significant.

**Discussion**

This is the first large sample study to assess the relationship between fluid intelligence and psychosocial adaptation. The overall results of our study suggest that fluid intelligence has a strong association with psychosocial measures. We found a linear relationship between RPM and measures of physical violence as the victimizer: the lower the RPM, the higher the violence score. We found a similar relationship between RPM and measures of violence pertaining to the victim role. No relation between RPM and psychological violence was found. Drug intake (especially for cannabis, cocaine and inhalants) was higher when RPM was lower. Self-esteem reports were modulated by 5 levels of RPM (from lower to higher) in a simple way: the lower the RPM, the lower the self-esteem. Finally, similar results were found for the mental health measurement: higher rates of health were observed when RPM was higher. All effects remained even whencovaried with parental educational level.

Deficits in fluid intelligence, executive functioning and social adaptation have been described after frontal lobe lesions [14–18,20–22]. Because all of these deficits have been linked to a common brain area, it is important to investigate the relationship between these deficits. While the relationship between executive functioning and fluid intelligence has already been established, investigations assessing the relationship between the latter and social adaptation are limited. Our data indicate that fluid intelligence is associated not only with executive function but is also a relevant component of psychosocial adaptation.

Complex modern societies demand a strong capacity for social adaptation. Bullying and violence, addictive behavior, perceived mental health and self-esteem are strongly linked with quality of life [96–102]. Our data evidence a straightforward association between levels of fluid intelligence and the degree of social adaptation. This is a novel result and opens up a new branch of research relating “cold” measures of intelligence to “hot” measures of socially-dependent behavior. Nevertheless, literature from other domains has produced some evidence of this relationship. For instance, Perry et al. [102] reported predictors of outcome in 332 children, aged 2–7 years, enrolled in the community-based Intensive Behavioral Intervention (IBI) program in Ontario, Canada and found that in the subset of children who had an IQ score available at intake ($n = 151$), there were significant and strong correlations between initial IQ and all outcome variables, mainly scales of adaptive behavior. Psychological adaptation problems, e.g., attention deficits, violence, patterns of antisocial, impulsive, norm-violating, sensation seeking and externalizing tendencies and substance use, have been linked to behavioral disinhibition [103]. In turn, behavioral disinhibition has been associated with reduced working memory and short-term memory capacity, as well as with lower IQ [104]. Various studies have shown an association between IQ in childhood or early adulthood and mortality in later life [105–109]. Consistent with our results, cognitive research has shown that sensitive parenting is linked with higher child IQ [110]. On the other hand, children who witness domestic violence tend to have significantly lower IQs [111] than their non-exposed peers [112–113]. There is also consistent evidence that relates low intelligence and delinquency [114–117]. As an example, Koolhof et al. [114] found that delinquents with low IQ were more behaviorally and cognitively impulsive than higher IQ delinquents. Additionally, low IQ offenders exhibited greater deficiency in empathy and guilt feelings that those with high IQ. Impulsivity, therefore, appears to be a key characteristic of low IQ.

Even though the aforementioned studies suggest a link between IQ and behavioral outcomes, no previous study has directly assessed the association between fluid intelligence and psychosocial adaptation. Ours is the first study to look for this association using a larger cohort and several measures of psychological adaptation. In addition, our sample is random and probabilistic, which is an uncommon design in studies of its type, they are usually carried out using convenience sample or intentional samples and provides greater generalizability of results and greater statistical power.

Our results need to be extended and replicated along several dimensions. First, our sample represents a socially vulnerable population and further studies should assess the relationship between fluid intelligence and psychosocial adaptation in other socioeconomic groups. In addition, further studies should include not only measures of fluid intelligence but also measures of crystallized intelligence to compare the effects of educational and cultural experience in interaction with fluid intelligence. Also, the inclusion of more objective and quantitative measures of psychosocial adaptation, such as experimental designs or brain studies, would provide an interesting, if challenging, approach to study the relationship between social adaptation and fluid intelligence.

Does low fluid intelligence itself make a person more vulnerable to social adaptation problems? Or is it that fluid intelligence is

| Regressand | RPM | Father’s education level | Mother’s education level |
|------------|-----|-------------------------|-------------------------|
|            | $\beta$ | Wald | OR CI$_{95\%}$ | $\beta$ | Wald | OR CI$_{95\%}$ | $\beta$ | Wald | OR CI$_{95\%}$ |
| Bully      | .33** | 76.37 | 1.29–1.50 | .030 | 4.47 | 1.00–1.06 | – .014 | .91 | .96–1.01 |
| Bullied    | .22** | 36.76 | 1.16–1.34 | .015 | 1.12 | 0.99–1.04 | – .018 | 1.62 | .96–1.01 |
| Use of illicit drugs | .43** | 28.52 | 1.31–1.79 | – .006 | .04 | .94–1.06 | – .009 | .09 | .93–1.05 |
| Intense physical violence | .25** | 31.98 | 1.18–1.40 | – .013 | .60 | .95–1.02 | .014 | .64 | .98–1.05 |
| Moderate physical violence | .09* | 6.10 | 1.02–1.18 | – .031 | 4.59 | .94–.99 | .044** | 9.40 | 1.02–1.08 |

*p < .05; **p < .01.

doi:10.1371/journal.pone.0024858.t005
correlated with the situation in which a person lives? For example, certainly lower intelligence is correlated with lower family income, so are we seeing the effects of poverty? Unfortunately, this is impossible to answer these questions with our data and further research is needed to address this topic. Nevertheless, at least some data suggest that the range of fluid intelligence is to some extent independent of socioeconomic and educational levels. Because we found that the effects of fluid intelligence on all measures of psychosocial adaptation remain once both socioeconomic and educational levels are covaried, we speculate that fluid intelligence is not completely dependent on socio-education. The association between fluid intelligence and psychosocial adaptation is very consistent in our data, the higher the first, the higher the second, between fluid intelligence and psychosocial adaptation is very consistent in our data, the higher the first, the higher the second.

A second issue concerning our results is the possible relationship between high fluid intelligence and social desirability. Specifically, could it be that fluid intelligence affects the tendency to answer questions in a socially desirable way? Unfortunately, we don’t have any direct way to address this point and the possibility that social desirability could act as a moderator effect in children with high RPM scores cannot be discarded. However, the relationship between a high RPM score and better psychosocial adaptation could be interpreted, from our point of view, as suggesting that children with higher fluid intelligence exhibit more adaptive behaviors than those who show low scores. Fundamentally, this can be sustained in students who report being less frequent victims of bullying at school, which in turn also correlates with a lower prevalence of domestic violence. Precisely, greater fluid intelligence implies that subjects will use the most effective strategies to deal with becoming a victim of aggression, both in school and at home. Therefore, the fact that children show higher fluid intelligence shouldn’t necessarily mean they avoid giving a sincere response about their situation. Future studies assessing implicit, not only explicit, measures of psychosocial adaptation will help to clarify the possible role of the moderator effect.

Finally, the relationship between executive function (EF), psychosocial adaptation and fluid intelligence calls for research. It is known that EFs are comprised of self-monitoring abilities. These functions are essential to goal-directed behavior, allowing us to maintain, update and integrate information to adapt and move within our environment [118].

Conclusion
This is the first report suggesting a clear relationship between fluid intelligence and psychosocial adaptation evaluated in several domains. These results call for a new branch of research that combines a neurocognitive approach to fluid intelligence with study of psychosocial adaptation.

Acknowledgments
We wish to thank two anonymous reviewers for their helpful criticism in earlier versions of the manuscript.

Author Contributions
Conceived and designed the experiments: DH MR LZ AL. Performed the experiments: DH LZ AC. Analyzed the data: DH AAR-R. Contributed reagents/materials/analysis tools: DH LZ AL. Wrote the paper: DH MR NS AC-J FM AL.

References
1. Catell RB (1963) Theory of fluid and crystallized intelligence: A critical experiment. J Educ Psychol 54: 1–22.
2. Catell RB (1971) Abilities: Their structure, growth and action. Boston: Houghton-Mifflin. 583 p.
3. Raven JC, Court HH, Raven J (2008) Test de matrices progresivas. Escalas coloreadas, general y avanzada. Manual. Buenos Aires: Paidós.
4. Mackintosh NJ, Bennet ES (2003) What do Raven’s matrices measure? An analysis in terms of sex differences. Intelligence 33: 663–674.
5. Jensen AR (1998) The g factor: The science of mental ability. Westport: CT7 Praeger 664 p.
6. Ivanovic R, Forno H, Durán M, Haidzún J, Castro C, et al. (2000) Estudio de la capacidad intelectual (Test de matrices progresivas de Raven) en escolares chilenos de 5 a 10 años. Antecedentes generales, normas y recomendaciones. Rev de Psicol Oral y Aplic 53: 3–50.
7. Duncan J, Burgess P, Emhie H (1995) Fluid intelligence after frontal lobe lesions. Neuropsychologia 33: 261–268.
8. Roca M, Parr A, Thompson R, Woolgar A, Torralva T, et al. (2010) Executive function and fluid intelligence after frontal lobe lesions. Brain 133(Pt 1): 234–247.
9. Woolgar A, Parr A, Cusack R, Thompson R, Nimmo-Smith I, et al. (2010) Fluid intelligence loss linked to restricted regions of damage within frontal and parietal cortex. Proc Natl Acad Sci U S A 107: 14989–14992.
10. Bishop SJ, Fossella J, Croucher CJ, Duncan J (2008) COMT val158met genotype affects recruitment of neural mechanisms supporting fluid intelligence. Cereb Cortex 18: 2132–2140.
11. Duncan J, Seitz RJ, Kolodny H, Bo D, Herzog H, et al. (2000) A neural basis for general intelligence. Science 289: 457–460.
12. Esposito G, Kirkby BS, Van Horn JD, Ellmore TM, Berman KF (1999) Context dependent, neural-system-specific neurophysiological concomitants of ageing: mapping PET correlates during cognitive activation. Brain 122: 963–979.
13. Prabhakaran V, Smith JAL, Desmond JE, Glover GH, Gabrieli JDE (1997) Neural substrates of fluid reasoning: An fMRI study of neocortical activation during performance of Raven’s Progressive Matrices Test. Cog Psychol 33: 45–63.
14. Laguet M, Coricelli G, Opolczyński G, Thibaut F (2010) Impaired decision making in schizophrenia and orbitofrontal cortex lesion patients. Schizophr Res 116: 266–273.
15. Shamay-Tsoory SG, Aharon-Peretz J, Perry D (2009) Two systems for empathy: a double dissociation between emotional and cognitive empathy in inferior frontal gyrus versus ventromedial prefrontal lesions. Brain 132(Pt 3): 617–627.
16. Shamay-Tsoory SG, Aharon-Peretz J (2007) Dissociable prefrontal networks for cognitive and affective theory of mind: a lesion study. Neuropsychologia 45: 3054–3067.
17. Baird A, Dewar BK, Critchley H, Dolan R, Shallice T, et al. (2006) Social and emotional functions in three patients with medial frontal lobe damage including the anterior cingulate cortex. Cogn Neuropsychiatry 11: 369–388.
18. Hynes CA, Baird AA, Grafton ST (2006) Differential role of the orbital frontal lobe in emotional versus cognitive perspective-taking. Neuropsychologia 44: 374–383.
19. Clark L, Manes F (2004) Social and emotional decision-making following frontal lobe injury. Neurocase 10: 398–403.
20. Clark L, Manes F, Antoun N, Sahakian BJ, Robbins TW (2003) The contributions of lesion laterality and lesion volume to decision-making impairment following frontal lobe damage. Neuropsychologia 41: 1474–1483.
21. Siegal M, Varley R (2002) Neural systems involved in “theory of mind”. Nat Rev Neurosci 3: 463–471.
22. Stone VE, Baron-Cohen S, Knight RT (1998) Frontal lobe contributions to theory of mind. J Cogn Neurosci 10(5): 649–656.
23. Dumontheil I, Thompson R, Duncan J (2011) Assembly and use of new task rules in fronto-parietal cortex. J Cogn Neurosci 23: 168–182.
24. Duncan J (2010) The multiple-demand (md) system of the primate brain: mental programs for intelligent behaviour. Trends Cogn Sci 14: 172–179.
25. Baddeley A, Emhie H, Kolodny J, Duncan J (1998) Random generation and the executive control of working memory. Q J Exp Psychol A 51: 819–852.
26. Bechara A, Damasio H, Tranel D, Anderson SW (1998) Disassociation of working memory from decision making within the human prefrontal cortex. J Neurosci 18: 428–437.
27. Bechara A, Tranel D, Damasio H (2000) Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. Brain 123(Pt 11): 2189–2202.
28. Damasio H, Grabowski F, Frank R, Galaburda AM, Damasio AR (1994) The return of Phineas Gage: clues about the brain from the skull of a famous patient. Science 264: 1102–1105.
29. Perfetti R, Saggino A, Ferretti A, Caolo M, Romani GL, et al. (2009) Differential patterns of cortical activation as a function of fluid reasoning complexity. Hum Brain Mapp 30: 497–510.
30. Bunting M (2006) Proactive interference and item similarity in working memory. J Exp Psychol Learn Mem Cogn 32: 183–196.
31. Bishop AJ, Kesper H, Holland CC, Forance A Jr, Siddon RL, et al. (2005) Increasing women’s intentions to stop smoking following an abnormal cervical smear test result. Prev Med 41: 179–185.
32. Rogosch F, Oishi A, Cicchetti D (2010) From child maltreatment to adolescent cannabis and dependence: A developmental cascade. Dev and Psychopathol 22: 883-897.

33. Cicchetti D, Valentino K (2006) An ecological/transactional perspective on child maltreatment: Failure of the average expectable environment and its influence upon child development. In: Cicchetti D, Cohen DJ, eds. Developmental psychopathology: Vol. 3. Risk, disorder, and adaptation. New York: Wiley. pp 129-201.

34. Cicchetti D, Rogosch FA (2002) A developmental psychopathology perspective on adolescence. J Consult Clin Psychol 70: 6-20.

35. Masten AS, Coatsworth JD (1998) The development of competence in favorable and unfavorable environments: Lessons from research on successful children. Am Psychol 53: 203-220.

36. Cicchetti D, Lynch M (1995) Failures in the expectable environment and their impact on individual development: The case of child maltreatment. In: Cicchetti D, Cohen DJ, eds. Developmental psychopathology: Vol. 2. Risk, disorder, and adaptation. New York: Wiley. pp 52-71.

37. Collins K, McAlroy G, Adamson G (2004) Bullying in schools: A Northern Ireland study. Educ Res 46: 55-71.

38. Nansel TR, Craig W, Overpeck MD, Saluja G, Ruan J (2004) Cross-national effects of age at start of puberty on mental health in pre-adolescence: results of a longitudinal study (1989–1991). [French]. Revue d Epidemiologie Et de Sante Publique 51: 317–328.

39. Roche P (2005) The impact of child abuse on未成年人's mental health: Evidence for the mediating role of perceived social support. J Child Maltreatment 30: 681-692.

40. Harkness KL, Lumley MN (2007) Child abuse and neglect and the development of depression in children and adolescents. In: Abele JR, Hinkin BL, eds. Handbook of depression in children and adolescents. New York: Guilford. pp 486-490.

41. Khatri P, Kupersmidt JB, Patterson C (2000) Aggression and peer victimization among children. Am Psychol 55: 749-771.

42. Collins K, McAulay G, Adamson G (2004) Bullying in schools: A Northern Ireland study. Educ Res 46: 55-71.

43. Chassin L, Hussong A, Beltran I (2009) Adolescent substance abuse. In: Cohen DJ, eds. Developmental psychopathology: Vol. 3. Risk, disorder, and adaptation. New York: Wiley. pp 620-636.

44. Bartels SJ, Pratt SI (2009) Psychosocial rehabilitation and quality of life for older adults with serious mental illness: recent findings and future research directions. Curr Psychiatry 22: 381–385.

45. Mason RJ, Crean R (2007) Acomprosate in the treatment of alcohol dependence: clinical and economic considerations. Expert Rev Neurother 7: 1465–1477.

46. Kurz MM (2006) Symptoms versus neurocognitive skills as correlates of psychosocial functioning in severe mental illness. Expert Rev Neurother 6: 47–56.

47. Vande W, Winther I, Rennie K (2011) Management of attention-deficit/hyperactivity disorder: The importance of psychosocial and medication treatment. J Pediatr Child Health, Jan 18. doi: 10.1111/j.1440-1754.2010.01941.x.

48. Spanner T (2009) Issues in the management of trouble with complex attention-deficit hyperactivity disorder symptoms. CNS Drugs 23: 5-8.

49. Dearing E (2008) Psychological costs of growing up poor. Ann N Y Acad Sci 1141: 141–162.

50. Grant BF, Stinson FS, Pope CE, Chou SP, Dufour RF, Ruan WJ, Ruan J (2009) Trends in the level of substance use among US youth: Prevalence and association with physical and psychosocial abused and substance use problems: A review. Clin Psychol Rev 22: 27–77.

51. Smith B, Liu T, Davies C, Boykin A, Elder M, et al. (2009) Risk factors in child maltreatment: A meta-analytic review of the literature. Agress Violent Behav 14: 13-29.

52. Milner JS, Dopke C (1997) Child physical abuse: Review of offender characteristics. In: Wolfe D, McEwen R, eds. Child abuse: New directions in prevention and treatment across the lifespan Banff international behavioral science series, vol. 4. Thousand Oaks, CA: Sage Publications, Inc. pp 27–54.

53. Abner JL, Allen JP (1987) Effects of Maltreatment on Young Children's Socioemotional Development: An Attachment Theory Perspective. Dev Psychopathol 1: 406–414.

54. Timberlake EM (1981) Child abuse and externalized aggression: preventing a delinquent life style. In: Hunner R, Walker E, eds. Exploring the relationship between child abuse and delinquency. Montgomery: Osman and Co. Washington.

55. Rourke RP (2008) Is neuropsychology a psychosocial science? J Clin Exp Neuropsychol 30: 691–699.

56. Towgood K, Ogden JA, Mee E (2004) Neurological, neuropsychological, and psychosocial outcome following treatment of untreated intracranial aneuro. J Neurology 251: 153–158.

57. Lesch TP, Seawright PM, O'Mara JM, Johnson WR (1996) Childhood psychopathology associated with the timing of pubertal development? J Am Acad Child Adolesc Psychiatry 35: 13–29.

58. Milner JS, Dopke C (1997) Child physical abuse: Review of offender characteristics. In: Wolfe D, McEwen R, eds. Child abuse: New directions in prevention and treatment across the lifespan Banff international behavioral science series, vol. 4. Thousand Oaks, CA: Sage Publications, Inc. pp 27–54.

59. Schorre BE, Vandvik IH (2004) Global assessment of psychosocial functioning in children. Am Psychol 53: 205–220.

60. Harkness KL, Lumley MN (2007) Child abuse and neglect and the development of depression in children and adolescents. In: Abele JR, Hinkin BL, eds. Handbook of depression in children and adolescents. New York: Guilford. pp 486-490.

61. Sourander A, Jenson P, Riihimäki S, Helenius H, et al. (2007) What is the early adulthood outcome of boys who bully or are bullied in childhood? The Finnish ‘From a Boy to a Man’ study. Pediatrics 120: 397–404.

62. Cicchetti D, Toth SL (2005) Child maltreatment. Annu Rev Clin Psychol 1: 105–130.

63. Simpson TL, Miller VR (2002) Comorbidity between childhood sexual and physical abuse and substance use problems: A review. Clin Psychol Rev 22: 27–77.

64. Bartels SJ, Pratt SI (2009) Psychosocial rehabilitation and quality of life for older adults with serious mental illness: recent findings and future research directions. Curr Psychiatry 22: 381–385.

65. Mason RJ, Crean R (2007) Acomprosate in the treatment of alcohol dependence: clinical and economic considerations. Expert Rev Neurother 7: 1465–1477.

66. Kurz MM (2006) Symptoms versus neurocognitive skills as correlates of psychosocial functioning in severe mental illness. Expert Rev Neurother 6: 47–56.

67. Vande W, Winther I, Rennie K (2011) Management of attention-deficit/hyperactivity disorder: The importance of psychosocial and medication treatment. J Pediatr Child Health, Jan 18. doi: 10.1111/j.1440-1754.2010.01941.x.

68. Spanner T (2009) Issues in the management of trouble with complex attention-deficit hyperactivity disorder symptoms. CNS Drugs 23: 5-8.

69. Dearing E (2008) Psychological costs of growing up poor. Ann N Y Acad Sci 1141: 324–332.

70. MacAllister WS, Boyd JR, Holland NJ, Milazzo MC, Krupp LB (2007) The psychosocial consequences of pediatric multiple sclerosis. Neurology 68(16 Suppl 2): S109–S115.

71. Schorr BE, VanSlyck IH (2004) Global assessment of psychosocial functioning in child and adolescent psychiatry. A review of three dimensional scales (CGAS, GAF, GADP). Eur Child Adolesc Psychiatry 13: 273–296.

72. Wingo AP, Harvey PD, Baldassarini R Jr (2009) Neurocognitive impairment in bipolar disorder patients: functional implications. Bipolar Disord 11: 115–125.

73. Kern RS, Glynn SM, Howan WF, Murder VR (2009) Psychosocial treatments to promote functional recovery in schizophrenia. Schizophr Bull 35: 347-361.

74. McEvoy JP (2006) Functional outcomes in schizophrenia. J Clin Psychiatry 67(Suppl 3): 20–24.

75. Brekke J, Hoe M, Long J, Green MF (2007) How neurocognition and social cognition influence functional change during community-based psychosocial rehabilitation for individuals with schizophrenia. Schizophr Bull 33: 1247–1256.

76. Yager JA, Elamnn TS (2007) Untangling social function and social cognition: a review of concepts and measurement. Psychiatry 69: 47-68.

77. McCagh J, Fisk JE, Baker GA (2009) Epilepsy, psychosocial and cognitive functioning. Epilepsy Res 86: 1–14.

78. Baker GA, Taylor J, Herrmann B (2009) How can cognitive status predispose to psychological impairment? Epilepsy Behav 15(Suppl 1): 31–35.

79. Wilson BA (2008) Neuropsychological rehabilitation. Annu Rev Clin Psychol 4: 141–162.

80. State of Delaware S.A. (2010) Delaware Bullying Questionnaire. Available: http://attorneygeneral.delaware.gov/schools/bulldustei.shtml. Accessed 2011 Jan 11.

81. Straus M (1979) Measuring intrafamily conflict and violence: The Conflict Tactics Scales (CTS). J Marriage Fam 41: 73–88.
92. Rosenberg’s M (1965) Society and the adolescent self-image. Princeton, NJ: Princeton University Press.

93. (2008) Consejo Nacional Para el Control de Estupefacientes, CONACE. Séptimo Estudio Nacional de Drogas en Población Escolar, 2007, de 5vo básico a 4to medio. Ministerio del Interior, Gobierno de Chile.

94. Hair JF, Anderson RE, Tatham RL, Black WC (1999) Análisis Multivariante. Madrid: Prentice Hall. 832 p.

95. Cohen J (1992) A power primer. Psychol Bull 112: 155–159.

96. Friesen A, Bjarnelind S (2010) Health-related quality of life and bullying in adolescence. Acta Paediatrica 32: 1913–1921.

97. Murphy H, Murphy E (2006) Comparing quality of life using the World Health Organization Quality of Life measure (WHOQOL-100) in a clinical and non-clinical sample: Exploring the role of self-esteem, self-efficacy and social functioning. J Ment Health 15: 289–300.

98. Perry A, Cummings A, Dunn Geier J, Freeman NL, Hughes S, et al. (2011) Predictors of outcome for children with autism in a large, community-based IBI program. International Meeting for Autism Research.

99. Hemmingsson T, Melin B, Allebeck P, Lundberg I (2006) The association between cognitive ability measured at ages 18–20 and mortality during 30 years of follow-up—a prospective observational study among Swedish males born 1949–51. Int J Epidemiol 35: 665–670.

100. Batty GD, Deary IJ, Gottfries LN (2007) Premorbid (early life) IQ and later mortality risk: systematic review. Ann Epidemiol 17: 278–280.

101. Silventoinen K, Modig-Wennerstad K, Tynelluus P, Rasmussen F (2007) Association between intelligence and coronary heart disease mortality: a population-based cohort study of 682,361 Swedish men and their parents. J Epidemiol Community Health 62: 722–727.

102. Koenen KC, Moffitt TE, Caspi A, Taylor A, Pardini D, et al. (2003) Childhood IQ and all-cause mortality before and after age 65: prospective observational study linking the Scottish mental survey 1932 and the midspan studies. Br J Health Psychol 10(Pt 2): 153–163.

103. Tamis-LeMonda CS, Shannon JD, Cabrera NJ, Lamb ME (2004) Fathers and mothers at play with their 2- and 3-year-olds: Contributions to language and cognitive development. Child Dev 75: 1806–1820.

104. Murphy H, Murphy E (2006) Comparing quality of life using the World Health Organization Quality of Life measure (WHOQOL-100) in a clinical and non-clinical sample: Exploring the role of self-esteem, self-efficacy and social functioning. J Ment Health 15: 289–300.

105. Wilkins-Shurmer A, O’Callaghan MJ, Najman JM, Bor W, Williams GM, et al. (2003) Association of bullying with adolescent health-related quality of life. J Paediatr Child Health 39: 436–441.

106. Perry A, Cummings A, Dunn Geier J, Freeman NL, Hughes S, et al. (2011) Predictors of outcome for children with autism in a large, community-based IBI program. International Meeting for Autism Research.

107. Iacono WG, Carlson SR, Taylor J, Elkins IJ, McGue M (1999) Behavioral disinhibition and the development of substance-use disorders: Findings from the Minnesota Twin Family Study. Dev Psychopathol 11: 899–900.

108. Bogg T, Fien PR (2010) A Self-Regulatory Model of Behavioral Disinhibition in Late Adolescence: Integrating Personality Traits, Externalizing Psychopathology, and Cognitive Capacity. J Pers 78: 441–470.

109. Modig-Wennerstad K, Silventoinen K, Barry D, Tynelluus P, Bergman L, et al. (2008) Association between offspring intelligence and parental mortality: a population-based cohort study of one million Swedish men and their parents. J Epidemiol Community Health 62: 722–727.

110. Koolhof R, Loeber R, Wei EH, Pardini D, D’Escurry AC (2007) Inhibition deficits of serious delinquent boys of low intelligence. Crim Behav Ment Health 17: 274–292.

111. Ferguson DM, Horwood LJ (2002) Male and female offending trajectories. Dev Psychopathol 14: 159–177.

112. Moffitt T, Rutter M, Caspi A, Taylor A, Pardelli S (2003) Developmental violence associated with environmental suppression of IQ in young children. Dev Psychopathol 15: 297–311.

113. Busch A, Lieberman A (2010) Mothers’ Adult Attachment Interview ratings predict preschool children’s IQ following domestic violence exposure. Attac Hum Dev 12: 505–527.

114. Silventoinen K, Hemmingsson T, Melin B, Allebeck P, Lundberg I (2006) The association between cognitive ability measured at ages 18–20 and mortality during 30 years of follow-up—a prospective observational study among Swedish males born 1949–51. Int J Epidemiol 35: 665–670.