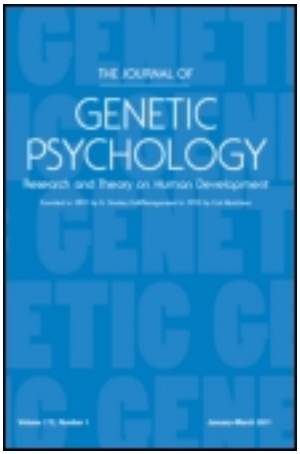
This article was downloaded by: [Aaron Hervey]
On: 24 January 2012, At: 16:56
Publisher: Routledge
Informa Ltd Registered in England and Wales Registered Number: 1072954
Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



The Journal of Genetic Psychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vgnt20

Heritability in Cognitive Performance: Evidence Using Computer-Based Testing

Aaron S. Hervey [a], Kathryn Greenfield [b] & C. Thomas Gualtieri [c]

[a] Duke University and North Carolina Neuropsychiatry

[b] Private Practice

[c] North Carolina Neuropsychiatry

Available online: 24 Jan 2012

To cite this article: Aaron S. Hervey, Kathryn Greenfield & C. Thomas Gualtieri (2012): Heritability in Cognitive Performance: Evidence Using Computer-Based Testing, The Journal of Genetic Psychology, 173:1, 112-118

To link to this article: http://dx.doi.org/10.1080/00221325.2011.573025

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: http://www.tandfonline.com/page/terms-and-conditions

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to

date. The accuracy of any instructions, formulae, and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand, or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

The Journal of Genetic Psychology, 2012, *173*(1), 112–118
Copyright © Taylor & Francis Group, LLC

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

BRIEF REPORT

Heritability in Cognitive Performance: Evidence Using Computer-Based Testing

AARON S. HERVEY
Duke University and North Carolina Neuropsychiatry

KATHRYN GREENFIELD
Private Practice

C. THOMAS GUALTIERI
North Carolina Neuropsychiatry

ABSTRACT. There is overwhelming evidence of genetic influence on cognition. The effect is seen in general cognitive ability, as well as in specific cognitive domains. A conventional assessment approach using face-to-face paper and pencil testing is difficult for large-scale studies. Computerized neurocognitive testing is a suitable alternative. A total of 267 parent–child dyads were selected from a larger database of computerized neurocognitive test results. Correlations were determined between parent–child dyads, as well as matched parent–child dyads. Univariate regression analyses were estimated to determine the extent to which children's performance could be accounted for by that of their parents, compared with matched control parents. Multiple significant positive correlations in neurocognitive test performance were found in parent–child dyads. Parent performance accounted for a greater proportion of variability in every case. These findings indicated that a computerized neurocognitive battery is an effective tool for studying heritability in cognitive performance in a large sample.

Keywords: assessment, genetics, heritability, neuropsychology, neuroscience

There is overwhelming evidence of genetic influence on individual differences in cognitive abilities, and that the genetic influence is substantial (de Geus, Wright, Martin, & Boomsma, 2001). Multivariate genetic research suggests that genetic effects are more general than specific or modular, and that general cognitive ability

Address correspondence to Aaron S. Hervey, North Carolina Neuropsychiatry, Department of Neuropsychology, 1829 East Franklin Street, 400 Franklin Square, Chapel Hill, NC 27514, USA; ahervey@ncneuropsych.com (e-mail).

is among the most heritable behavioral traits (Plomin & Craig, 1997). The heritability of IQ increases from 30% at age 5 years to 80% at age 12 years (Polderman et al., 2006), and in studies of adults and older people, heritability estimates range from 52% to 85% (Plomin, Pedersen, Lichtenstein, & McClearn, 1994; Finkel, Pedersen, McGue, & McClearn, 1995; Posthuma, de Geus, & Boomsma, 2001; Wright et al., 2001). Genetic effects are exercised on virtually every phenotype. High levels of heritability are found, for example, in tests of executive function (EF), attention, memory, working memory, reaction time, verbal reasoning, and information processing speed. Academic tests of mathematics and reading are also heritable to a moderate degree and show only modest shared environmental influence.

Present approaches to trace genes responsible for variation in the normal ranges of cognitive ability consist of large scale linkage and association studies. These have been hampered by low statistical power to detect quantitative trait loci of small effect (Plomin & Craig, 1997). One potential solution to these problems is to conduct large-scale studies in selected populations. However, this presents a logistical problem, due to the difficulties intrinsic to cognitive evaluation on a mass scale. Traditional neuropsychological batteries provide a broad and deep pool of information, but they take several hours to conduct and require special training to score and interpret. Ultimately, these studies are cost-prohibitive with large samples, let alone for population studies.

Theoretically, computerized testing can solve that problem. A neurocognitive test battery suitable for large-scale genetic research should cover a wide range of cognitive abilities but also be short, efficient, and easy to complete. To date, no studies have been published addressing the issue of whether this type of assessment can reliably identify cognitive similarities based on genetic similarities. Most existing computerized batteries are inappropriate for such research for a variety of reasons: They use idiosyncratic measures, are based on highly specific experimental paradigms, do not have an established normative structure, do not generate standard scores which permit comparison between people of different ages, or generate only individual test scores, rather than a general measure of cognitive ability.

Nevertheless, there is substantial precedent for using computerized testing to study cognitive functioning, dating at least to the work of Rosvold et al. (1956) in the mid-1950s. Moreover, one need only consider the schizophrenia (Almasy et al., 2008), attention deficit hyperactivity disorder (ADHD; Doyle et al., 2008), or functional neuroimaging literatures more generally to find widespread use of individual computer-based neuropsychological tests in studying the cognition of genetically similar individuals. Research incorporating functional neuroimaging to study cognition actually requires computerized tests.

In the present study, we investigated the feasibility of genetic research using a computerized test battery by examining whether similarities in performance could be identified between parent and child dyads on a computerized neurocognitive

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

battery. We hypothesized that the performance of children on this test battery would be more similar to that of their biological parents than to that of a matched sample of unrelated adults. Relevant demographic variables were controlled. Therefore, similarity in performance would reflect the phenotypic expression of familial heritability. Further, we attempted to identify the degree to which heritability accounted for variation in performance.

Method

Participants

A total of 267 parent–child dyads ($N = 534$) was selected from an extensive database containing >8,000 records of performance on a computerized neurocognitive test battery, CNS Vital Signs (CNS VS). The 534 participants constituted all parent–child dyads from the database with complete sets of test data. An additional 267 individuals were matched to the parents in the parent–child dyads. All participants provided informed consent and assent. Matched participants were selected randomly based on matches of four variables in the following order: age (within 5 years), gender, race, and education (within 3 years). Demographic variables for the parents, matched parents, and child groups, were the following: for parents, average age was 45.9 years ($SD = 8.9$ years), 68% were women, 92% were Caucasian, average education was 15.8 years ($SD = 2.5$); for matched parents, average age was 45.9 years ($SD = 9.0$ years), 68% were women, 92% were Caucasian, average education was 15.8 years ($SD = 2.1$); for child, average age was 15.2 years ($SD = 7.7$ years), 36% were girls, 92% were Caucasian, average education was 8.2 years ($SD = 3.8$). Education data were available for 247 participants in the parent group, 228 participants in the matched parent group, and 181 participants in the child group. When education data were not available for the matched parent participants, match was based on the remaining demographic variables. The matched sample represented patients, patient family members, and non-patients recruited from three neuropsychiatric clinics in North Carolina.

Neurocognitive Evaluation

The CNS VS battery contains 10 subtests that are known to be reliable and valid. The subtests span multiple cognitive domains, and are known to be sensitive to causes of mild cognitive dysfunction. Additional information about the test-retest reliability, concurrent validity, and discriminant validity of this test battery is readily available (Gualtieri & Johnson, 2006).

Each of the subtests on the CNS VS battery generates several individual subtest scores (e.g., correct responses, errors of omission and commission, reaction time). Domain scores are calculated from individual subtest scores. The domain

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

scores are converted to z scores on the basis of the subject's age, and then standardized, or expressed as standard scores, with a mean of 100 and a standard deviation of 15. Thus, the scores of individuals of different ages can be directly compared. The z scores of the seven tests in the CNS VS core battery are then averaged to generate a standard composite score, the Neurocognition Index (NCI).

Results

Bivariate Pearson product moment correlations assessed the broad relation between performance in the three groups: parents, matched parents, and children. A conservative p value ($p < .01$) was adopted to account for the high number of comparisons. Significant positive correlations between parents and children were found on six of 14 standard score test domains, including the composite index (NCI; $r = .262$), as well as the domains of psychomotor speed (.216), cognitive flexibility (.311), nonverbal reasoning (.248), working memory (.235), and executive function (.299). By comparison, significant positive correlations were found between the matched adult and child groups for only one domain: psychomotor speed ($r = .170$).

Secondary analysis of significant correlations was conducted by using univariate regression models to estimate the variability in child performance that was accounted for by the linear relationship with parent or matched parent performance (see Table 1). Regression analyses indicated that each of the six parent test variables uniquely predicted a portion of the variance in child test performance on the same variables.

Discussion

Cognitive assessment using computerized testing has inherent advantages and disadvantages compared to traditional face-to-face testing. Advantages include the ease with which large samples can be tested rapidly and consistently with minimal provider support. In the present study we set out to determine whether a computerized test battery, with these inherent advantages, could be used to identify performance similarities in genetically similar groups. Ideally, identifying such an instrument would fulfill the long-term goal of expanding the tools available for studying cognition and genetics.

The results from the present study suggest that a computerized cognitive test battery is capable of identifying performance similarities between genetically related groups after accounting for the effects of age, gender, race, and education. Children performed similarly to their biological parents on multiple measures, consistent with research highlighting the relation between genetic similarity and cognitive similarity (de Geus et al., 2001). That these performance similarities can be identified using a computerized battery in a large sample is the unique contribution of this work. Further, this battery dissociates performance between

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

TABLE 1. Results of Univariate Regression Analyses for Parent–Child and Matched Parent–Child Performance

	Parent–child					Matched parent–child				
Cognitive measure	*F*	*df*	*p*	CI	r^2	*F*	(*df*)	*p*	CI	r^2
NCI	17.542	1, 238	<.001	[.157, .435]	.069	2.617	1, 221	*ns*		n/a
Psychomotor speed	12.195	1, 248	.001	[.107, .385]	.047	6.951	1, 234	.009	[.035, .245]	.029
Cognitive flexibility	25.888	1, 241	<.001	[.211, .478]	.097	3.741	1, 227	*ns*		n/a
Nonverbal reasoning	8.248	1, 126	.005	[.092, .501]	.061	0.521	1, 96	*ns*		n/a
Working memory	7.278	1, 125	.008	[.075, .488]	.055	1.481	1, 90	*ns*		n/a
Executive function	23.843	1, 242	<.001	[.195, .458]	.090	2.984	1, 231	*ns*		n/a

Note. NCI = Neurocognition Index; CI = confidence interval; n/a = not applicable.

parents and a demographically similar but nongenetically related group. By and large, performance similarities could not be identified between groups that were not genetically related.

The results of the present study suggest that the genetic influence on cognition is most strongly represented in the CNS VS variables of psychomotor speed, cognitive flexibility, nonverbal reasoning, working memory, and executive function, as well as a summative overall measure, the NCI. They also indicate that a comprehensive computerized test battery may be suitable for large-scale genetic research, with particular emphasis on those variables found to be related in this sample.

There are several potential limitations of the present work. First, this study was completed using a data set composed of patients with neuropsychiatric disorders typically seen in the outpatient setting and nonpatients. Moreover, some of the patients were treated at the time the present data were collected and some were untreated. However, the parent groups were selected from the same pool of individuals and there is no systematic factor suggesting that the degree of overall psychiatric dysfunction differs between the two groups. Further, the fact that these findings persisted after accounting for this variability in patient and treatment status actually bolsters confidence in them.

In the present study we attempted to account for those variables beyond genetic contribution, which are most influential in cognitive functioning, namely age and education, as well as other demographic factors. These variables were thought to represent a limited but reasonable accounting of those nongenetic factors in a large diverse sample. Nevertheless, the potential environmental contributors to cognitive function are nearly limitless, and this should be recognized. In some sense, accounting for these factors may have diminished the magnitude of the results, considering that there is a degree of shared variance between demographic factors and cognitive performance that could more appropriately be attributed to genetic makeup rather than environment.

The present findings raise a number of interesting issues to be targeted in future work. For example, do genetically mediated performance profiles vary by diagnosis? Might profiles exist which represent endophenotypes? Certainly this is being carefully considered in ADHD (Doyle et al., 2008) and schizophrenia (Bertisch Li, Hoptman, & DeLisi, 2010), among other disorders. Likewise, this information can potentially be used as a means to measure medication response (McGough, 2005) and integrate developing technology (e.g., functional neuroimaging, electroencephalography) to further advance the field of cognitive functioning and genetics.

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

AUTHOR NOTES

Aaron S. Hervey, Ph.D., ABPP, is a board-certified neuropsychologist. He is in private practice in North Carolina and is also affiliated with Duke University.

Kathryn Greenfield, M.A., is a licensed practitioner in private practice in Colorado. **C. Thomas Gualtieri**, MD is a neuropsychiatrist and the medical director of North Carolina Neuropsychiatry.

Downloaded by [Aaron Hervey] at 16:56 24 January 2012

REFERENCES

Almasy, L., Gur, R. C., Haack, K., Cole, S. A., Calkins, M. E., Peralta, J. M., et al. (2008). A genome screen for quantitative trait loci influencing schizophrenia and neurocognitive phenotypes. *American Journal of Psychiatry*, *165*, 1185–1192.

Bertisch, H., Li, D., Hoptman, M. J., & DeLisi, L. E. (2010). Heritability estimates for cognitive factors and brain white matter inetrity as markers of schizophrenia. *American Journal of Medical Genetics, Part B: Neuropsychiatric Genetics*, *153B*, 885.

de Geus, E. J., Wright, M. J., Martin, N. G., & Boomsma, D. I. (2001). Genetics of brain function and cognition. *Behaviour Genetics*, *31*, 489–495.

Doyle, A. E., Ferreira, M. A., Sklar, P. B., Lasky-Su, J., Petty, C. Fusillo, S. J., et al. (2008). Multivariate genomewide linkage scan of neurocognitive traits and ADHD symptoms: Suggestive linkage to 3q13. *American Journal of Medical Genetics. Part B, Neuropsychiatric Genetics*, *147B*, 1399–1411.

Finkel, D., Pedersen, N. L., McGue, M., & McClearn, G. E. (1995). Heritability of cognitive abilities in adult twins: A comparison of Minnesota and Swedish data. *Behaviour Genetics*, *25*, 421–431.

Gualtieri, C. T., & Johnson, L. G. (2006). Reliability and validity of a computerized neurocognitive test battery, CNS vital signs. *Archives of Clinical Neuropsychology*, *21*, 623–643.

McGough, J. J. (2005). Attention-deficit/hyperactivity disorder pharmacogenomics. *Biological Psychiatry*, *1*, 1367–1373.

Plomin, R., & Craig, I. (1997). Human behavioural genetics of cognitive abilities and disabilities. *BioEssays*, *19*, 1117–1124.

Plomin, R., Pedersen, N. L., Lichtenstein, P., & McClearn, G. E. (1994). Variability and stability in cognitive abilities are largely genetic later in life. *Behaviour Genetics*, *24*, 207–215.

Polderman, T. J., Gosso, M. F., Posthuma, D., Van Beijsterveldt, T. C., Heutink, P., Verhulst, F. C., & Boomsma, D. I. (2006). A longitudinal twin study on IQ, executive functioning, and attention problems during childhood and early adolescence. *Acta Neurologica Belgica*, *106*, 191–207.

Posthuma, D., de Geus, E. J., & Boomsma, D. I. (2001). Perceptual speed and IQ are associated through common genetic factors. *Behaviour Genetics*, *31*, 593–602.

Rosvold, H. E., Mirsky, A. F., Sarason, I., Bransome, E. D., & Beck, L. H. (1956). A continuous performance test of brain damage. *Journal of Consulting Psychology*, *20*, 343–350.

Wright, M., de Geus, E., Ando, J., Luciano, M., Posthuma, D., Ono, Y., et al. (2001). Genetics of cognition: Outline of a collaborative twin study. *Twin Research and Human Genetics*, *4*, 48–56.

Original manuscript received December 7, 2010
Final version accepted February 25, 2011