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Inspection time and IQ Fluid or perceptual aspects of intelligence?

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Abstract

Past research has found an association between inspection time (IT) and fluid intelligence using measures confounded with visual processing (e.g., Wechsler PIQ or Ravens Progressive Matrices). The present study related IT to intelligence using a measure (Woodcock–Johnson—Revised, WJ-R) that has nonconfounded factors of mental ability in order to determine whether the association is based upon fluid IQ or perceptual processes. Thirty-seven undergraduate students were given fluid, crystallized, and visual processes subtests from the Woodcock–Johnson and a visual IT task. Stepwise multiple regression and partial correlations revealed that IT was related only to fluid intelligence (range corrected correlation of −.74), supporting the notion that IT reflects some fundamental underlying aspect of intelligence such as neural processing efficiency.

Keywords: Inspection time; Fluid intelligence

1. Introduction

Inspection time (IT; speed of apprehension of a simple stimulus determined by varying exposure time rather than response time) has been found to break the .3 correlation barrier in predicting intelligence (Deary & Stough, 1996) and has been touted as a

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possible measure of the biological underpinnings of intelligence (Jensen, 1998). IT has been controversially defined as a measure of speed of apprehension or processing, which may reflect the fundamental and elemental facet of intelligence (Brand, 1984; Nettelbeck & Kirby, 1983). The procedure varies the duration of a simple visual (or auditory or tactile) stimulus, rectifying several problems associated with traditional reaction time (RT) approaches to measuring speed of mental processing. Specifically, by ignoring the participant's speed of responding to the stimulus, confounds of movement time and executive processes (associated with rapid responding and decision-making requirements) are eliminated. Instead, the duration of stimulus exposure necessary to achieve a specified criterion of accuracy of response (97.5%; Nettelbeck, 1982) is the operative dependent variable. In this fashion, IT is thought to relate to intellectual processes more specifically than RT procedures, which are necessarily confounded with movement and decision time.

Despite elimination of motor speed, IT has been found to be related predominantly to the performance intelligence quotient (PIQ) in healthy adults, with little relationship to the verbal intelligence quotient (VIQ) (Deary, 1993; Nettelbeck, 1987). A meta-analysis by Kranzler and Jensen (1989) finds a $-.69$ corrected correlation between IT and PIQ in adults, whereas the comparable value for VIQ is only $-.27$. Using confirmatory factor analysis, McGeorge, Crawford, and Kelly (1996) used a sample matched to UK census data, verifying that IT relates better to PIQ than other aspects of intelligence. On the basis of the IT–PIQ correlation, some authors (e.g., Deary & Stough, 1996; Nettelbeck & Rabbitt, 1992) argue that this correlation reflects the relationship between IT and fluid aspects of intelligent behavior (Horn & Cattell, 1967). However, PIQ (and other measures used, such as the Ravens Progressive Matrices) also reflects visual processing (Carroll, 1993; McGrew, 1994). In fact, Crawford, Deary, Allan, and Gustafsson (1998) found by confirmatory factor analysis methods that a model in which visual IT related to both general intelligence and an orthogonal visual processes aspect of intelligence provided a better fit to the data than a model where IT related either to general or to visual aspects of intelligence alone. Thus, two vastly different hypotheses about how IT relates to intelligence can be conceived.

The first hypothesis (Fluid Intelligence Hypothesis) argues that IT reflects some bases of all intelligent behaviors because it measures a fundamental cognitive attribute, such as speed of neural processing. This attribute is thought to be most reflected in the fluid aspects of intelligence (Brand, 1984), as fluid intelligence requires optimal efficiency in neural functioning. This efficiency is most important in measures of novel problem solving where effortful and integrated cognitive activities are required, such as occurs on the Woodcock–Johnson—Revised (WJ-R) measures of fluid intelligence: Analysis–Synthesis and Concept Formation (Woodcock & Johnson, 1989). On the other hand, measures of crystallized intelligence require noneffortful retrieval of overlearned information with few requirements on neural efficiency and integrated cognitive activity. Thus, IT would not be expected to relate as highly, or even at all, to crystallized intelligence. However, a second hypothesis would hold that IT requires the crucial component of one aspect of intelligence and is not an underlying facet of all intelligent behavior.

This second hypothesis (Visual Perceptual Hypothesis) holds that the IT task reflects neural processing only in the visual perceptual system rather than that underlying all intelligent behaviors. This view is suggested by the dissociation between auditory and visual IT paradigms (e.g., Nettelbeck, Edwards, & Vreugedenhil, 1986, found only a .39 correlation between auditory and visual IT formats). Also, these authors found that IT correlates with all PIQ subtests and PIQ, while its relationship to VIQ, when it occurs, happens in the context of no correlation with any of the individual VIQ subtests. That is, some common variance across the PIQ subtests (presumably perceptual organization) and some unique variance pooled across the VIQ subtests are accounting for these high IT–IQ correlations. These authors concluded that IT reflects efficiency of "early, central *perceptual* (emphasis added) activity." This position fits with a review of data by Levy (1992) in which it was concluded that differences in IT are better accounted for by cognitive differences associated with verbal and perceptual aspects of the task rather than by differences in "effective sensory registration and icon maintenance." Thus, under this scenario, IT might be expected to relate more strongly to measures of visual perceptual ability, especially object recognition (as opposed to spatial functions; Mishkin & Appenzeller, 1990). Since previous studies have used measures (PIQ and Ravens Progressive Matrices) that confound visual processing and fluid intelligence, the two hypotheses have not been adequately differentiated. This confounding is evident in comparisons between the Wechsler scales and the Woodcock–Johnson measures of intelligence. Citing factor-analytic studies, McGrew (1994) compares the Wechsler scales of intelligence with the WJ-R measures of intelligence, finding that PIQ scales load most prominently with the WJ-R Visual Processing scales/factor rather than the Fluid Intelligence scales/factor. Thus, use of the Wechsler PIQ, and even the Ravens Progressive Matrices, is not the best way to test the hypothesis that IT relates to fluid intelligence.

Comparing postulates of the two hypotheses (Fluid vs. Visual Perceptual) mentioned above, an empirical test is warranted to further study the relationship between IT and intelligence. If the first (Fluid Intelligence) hypothesis is correct, IT should relate more strongly to the WJ-R factor of fluid intelligence (Gf) than to the visual processing factor (Gv). However, if the second (Visual Perceptual) hypothesis is correct, then the opposite relationship between IT and two factors of intelligence (fluid vs. visual processing) should be obtained, i.e., IT should relate more strongly to Gv than to Gf. Furthermore, since crystallized intelligence (Gc) on the Woodcock–Johnson measure of intelligence relates strongly to VIQ (McGrew, 1994) and VIQ relates weakly, if at all, to IT, then Gc can be used as a discriminant measure. Neither hypothesis predicts a relationship between IT and VIQ/Gc.

Therefore, the present study examines the relationship between IT and three aspects of intelligence using three factors from the Woodcock–Johnson Battery of Cognitive Ability—Revised. The visual processing factor (Gv) and the fluid intelligence factor (Gf) were used in order to examine whether IT relates more to visual perceptual abilities or to basic neural processing efficiency represented in fluid intelligence. The crystallized intelligence factor (Gc) was included as a measure of discriminant validity. Correlations, partial correlations, and multiple regression were used to evaluate the relationships between IT and the various aspects of intelligence.

2. Method

2.1. Participants

Participants included 40 college students, 19 male and 21 female, who took part in the study for extra credit. One participant was lost due to examiner error when the IQ tests were not administered. In addition, two participants were eliminated because of greater than 3 S.D. outlier performance on the IT task, occurring apparently due to insufficient effort during task performance. The mean age of the remaining 37 participants was 23.61 (S.D. = 7.04) and the mean IQ (average of Gc, Gf, and Gv) was 103.35 (S.D. = 8.84) with values of the three factors being: Gv = 100.43/11.35, Gc = 103.78/11.52, and Gf = 105.84/10.56. Mean IQ was roughly normally distributed (skew = 0.183) with a range of 86–123. Because of the restricted range of the IQ variance, correlations were corrected according to standard procedures, as seen in Table 1 (Hunter & Schmidt, 1990). All participants were free of learning disability diagnoses, neurological diagnoses, or psychiatric medication. In addition, normal or corrected-to-normal vision was reported by all participants. The study was conducted according to ethical guidelines for human participation in research.

2.2. Procedure

A typical IT stimulus was created according to standard procedures (e.g., Vickers & Smith, 1986). A pi symbol stimulus was used, which consisted of legs of different length, varying by 1° of visual angle in order to make the stimulus appropriately greater than the 0.3° value of internal noise (Vickers & Smith, 1986). The stimulus subtended a visual angle of approximately 2°, with the shorter segment occurring with equal probability on either the right or left side of the stimulus. A standard overlapping backward mask was used, consisting of a thicker version of the stimulus where both legs were equal in length to prevent a lingering internal representation of the stimulus in iconic memory. The stimulus was exposed at nine different durations, occurring in random order from 20 to 110 ms (method of constant stimuli; Vickers,

Table 1
Zero-order, partial, and corrected zero-order correlations between IT and visual processing (Gv), fluid (Gf), and crystallized (Gc) intelligence

IQ	Zero order	Partial Correlations		Corrected zero order
Gv	− .47**	− .22 (Gf)	− .50 (Gc)***	− .59***
Gf	− .63***	− .51 (Gv)***	− .66 (Gc)***	− .74***
Gc	− .05	.19 (Gv)	.27 (Gf)	− .07

All values represent correlations between IT total errors and the labelled aspect of intelligence. IQ labels in parentheses under the Partial correlation column represent the variable controlled for in the partial correlation. Correlations in the last column are zero-order correlations corrected for range restriction. Gv = visual processing IQ; Gf = fluid IQ; Gc = crystallized IQ.

* $P<.05$.

** $P<.01$.

*** $P<.001$.

1979). The mask immediately followed the stimulus and was shown for a duration of 1000 ms. In order to insure adequate attention, a cue (cross-located midway between the area where the two legs of the stimulus would appear) preceded the exposure of the stimulus and lasted 1000 ms.

Cue, stimulus, and backward mask were presented in the three channels of a Gerbrands Tachistoscope (model T-33-1), in respective order. A Gerbrands Lamp Drive Circuit (model 400-3) and a Timer (model 300-6 T) were used to control the tachistoscope and the apparatus was calibrated at the beginning and ending of the experiment using a digital readout oscilloscope to insure accurate stimulus duration exposures to within 5% error.

Participants were instructed in the procedure and given 10 practice trials to insure adequate understanding of the task and to equilibrate initial performance across participants. A total of 90 trials were administered in the IT procedure with 10 trials at each of 9 exposure times.

Six tests of the WJ-R were administered in order to obtain three factor scores: Gv (Visual Processes), Gc (Crystallized Intelligence), and Gf (Fluid Intelligence). Those six tests included: Visual Closure (Test 5) and Picture Recognition (Test 12) composing Gv; Picture Vocabulary (Test 6) and Oral Vocabulary (Test 13) composing Gc; and Analysis–Synthesis (Test 7) and Concept Formation (Test 14) composing Gf. Intelligence tests were administered in standard order, and order of the intelligence testing and IT procedure was counterbalanced across subjects with half receiving first the intelligence testing and half receiving the IT procedure first.

3. Results

IT times followed the expected normal ogive curve with a mean IT for the group of 107 ms, using the standard 97.5% accuracy criterion and a traditional pi stimulus and mask. IT–IQ correlations are evident in Table 1, demonstrating moderately strong correlations between IT and Gv and Gf and no relationship with Gc. The relationship between IT and Gv became nonsignificant in a partial correlation (− .22) that controlled for its relationship with Gf. The partial correlation between IT and Gf remained significant (− .51) when controlling for its relationship with Gv. The uncorrected Gf–IT correlation is − .63 with a 95% confidence interval of − .38 to − .79. In addition, Table 1 shows range restriction corrected correlation values of zero-order correlations. Forward stepwise multiple regression (as suggested by Cohen & Cohen, 1983, for use in prediction, as opposed to explanation where hierarchical regression is preferred) was used to predict IT using Gf, Gv, and Gc. Gf was the only significant predictor [adjusted R^2=.38, $F(1,37) = 22.62$, $P < .0001$].

4. Discussion

Past findings of a relationship between fluid intelligence (in this study the Gf measure from the Woodcock–Johnson test) and IT (Brand, 1984; Nettelbeck & Kirby, 1983) are corroborated by results of the present study. Present results most strongly support the first hypothesis

(Fluid Intelligence), which states that IT reflects some fundamental aspect of intelligent behavior such as neural processing efficiency. This support is found in the multiple regression results, since only fluid intelligence measures (Gf) predict IT with statistical significance. Likewise, taking visual processes (Gv) variance out of Gf using partial correlation does little to decrease its relationship with IT.

The present results do not support the second hypothesis (Visual Perceptual Hypothesis), since partial correlations demonstrate that the significant relationship between IT and visual processing (Gv) is eliminated when common variance between Gv and Gf is controlled. In addition to finding an association between IT and fluid intelligence, there was no relation between IT and crystallized intelligence (Gc), as predicted by both hypotheses. Furthermore, partial correlations extracting both Gf and Gv were unsuccessful in bringing to light a latent correlation between IT and Gc.

Given support for the first hypothesis and lack of such for the second hypothesis, it is concluded that IT is specifically associated with some aspect of fluid intelligence. While past findings confounded visual processing and fluid intelligence, the present results used more differentiated measures in order to better separate visual and fluid aspects of intelligence and still found IT to be more related to Gf than to other measures of intelligence. The present results allow a more confident assertion that IT reflects some fundamental underlying aspect of intelligent behavior, perhaps neural efficiency. However, the lack of correlation between IT and other aspects of intelligence (e.g., Gc) argues against the interpretation, sometimes advanced, that this more fundamental ability is elemental to all intelligent behaviors (Brand, 1984).

Also interesting, the present results found a higher corrected correlation between IT and fluid intelligence (− .74) than typically found in past studies. The most accepted figure is that reported by Kranzler and Jensen (1989) in a review of the literature where a corrected correlation of − .5 between IT and fluid intelligence is found. In addition to sampling error, the reason for the increased correlation in the present study may be related to the use of a more differentiated measure (Woodcock–Johnson) where fluid intelligence is separated from other aspects of intelligence, most notably visual processes and crystallized intelligence. In addition, the Woodcock–Johnson measure is developed according to newer integrations of intellectual processes based upon factor analysis models that have excellent consistency across a large body of literature (Carroll, 1993; Jensen, 1998). The current measure of fluid intelligence is not confounded with other factors of intelligence, as is the case with Wechsler PIQ and Raven Progressive Matrices. Without that confound, the current method possibly provides a better delineation of the construct (e.g., neural processing efficiency), which is thought to underlie the IT and fluid intelligence correlation.

Three limitations of the present study are important to consider. First, some controversy about the use of corrections for correlation coefficients exists. However, controversy about the use of corrected correlations exists primarily because assumptions necessary for their use are not often tested (Hunter & Schmidt, 1990). Two assumptions for restriction of range correction are important: (a) linear relationships between the variables of interest and (b) homoskedasticity. These assumptions were evaluated in the present study by visual analysis of scatterplots and residuals analyses (Fig. 1). No difficulties with the assumptions were

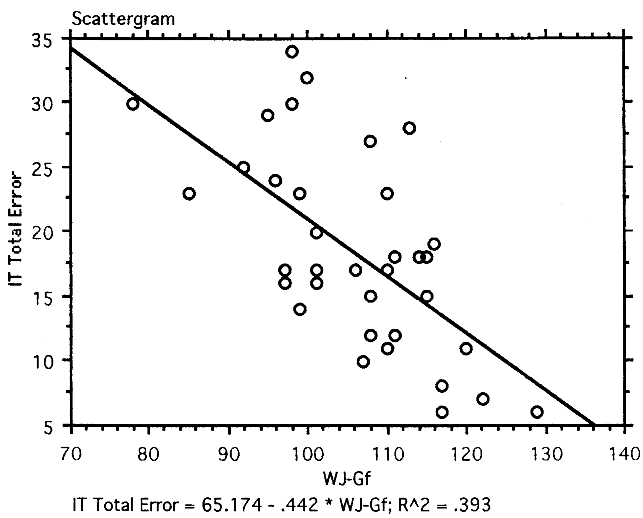

Fig. 1. Scattergram of the relationship between total errors on IT task and the fluid intelligence score on WJ-R (WJ–Gf).

evident. With those assumptions accounted for, corrections typically substantially reduce systematic error in correlations, making their use in this circumstance important (Hunter & Schmidt, 1990, pp. 122–128). Their use was important in this study because of the homogeneous performance on IQ measures of the college student population. That is, low-intelligence participants are underrepresented in the sample, constraining variance on the IQ score distribution. It is this restriction in variance that the corrections are designed to ameliorate. A more heterogeneous sample or a different noncollege student homogeneous sample may yield a different relationship between IT and intelligence. Further research is needed to address this possibility.

A second limitation of the study concerns the small sample size. It is possible that the large correlation between Gf and IT is a result of sampling error and that increasing sample size would decrease the correlation, bringing it more into line with the accepted value of .5 (Kranzler & Jensen, 1989). However, the confidence interval (.38–.79) includes accepted values of the relationship between IT and intelligence, indicating the similarity of present findings to past research and corroborating the representativeness of the current sample.

A third limitation of the present results involves the mask used. Recent work (Evans & Nettelbeck, 1993) has demonstrated that a traditional IT mask underestimates the true IT because approximately 50% of college student participants utilize an "apparent motion" strategy to circumvent the utility of the backward mask. This strategy allows quicker presentation rates to be perceived, making IT values inaccurately low. Nettelbeck suggests using a "flash" mask, which prevents the "apparent motion" effect, to measure IT more accurately. Since the present study used a traditional IT mask in a college student sample, present IT values should not be used as a true reflection of IT speed.

However, this limitation is not expected to detract from the primary construct validity purpose of the study, although replication using the new mask would be prudent. In fact, a follow-up study using the new mask of Evans and Nettelbeck (1993), which reduces the effects of participant strategies (apparent motion effect), would be interesting for its effect on the IT–Gf correlation. If, in fact, the correlation is partially accounted for by a participant's ability to discover the apparent motion effect, then the theoretical significance of the correlation would be altered.

In fact, a recent study (Burns, Nettelbeck, & Cooper, 1999) using the flash mask found no correlation between IT and a fluid measure of intelligence similar to the one used in the present study. These results contradict the present study's findings and need explanation. It is possible that the current results are explained by a third variable that mediates the IT and Gf relationship. The Burns et al. results argue that processing speed (Gs) mediates the IT–Gf correlation. However, further studies are needed to resolve this issue since the current results find a relatively high correlation between IT and Gf and they are based upon a more stable measure of Gf (two Woodcock–Johnson tests vs. only one in the Burns et al. study).

Apart from the future work already mentioned, a further test of the Fluid Intelligence Hypothesis could be obtained by replicating the present study using auditory, instead of visual, IT. If IT reflects some fundamental components of fluid intelligence, then changing the perceptual modality of the IT stimulus should have little effect upon their correlation. The auditory processing factor (Ga) on the Woodcock–Johnson test could be used in a similar fashion as the Gv factor was used in the present study.

References

Brand, C. R. (1984). Intelligence and inspection time: an ontogenetic relationship? In: C. J. Turner, & H. B. Miles (Eds.), *The biology of human intelligence*. Nafferton, UK: Nafferton Books.

Burns, N. R., Nettelbeck, T., & Cooper, C. J. (1999). Inspection time correlates with general speed of processing but not with fluid ability. *Intelligence*, *27*, 37–44.

Carroll, J. B. (1993). *Human cognitive abilities: a survey of factor-analytic studies*. New York: Cambridge University Press.

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavior sciences*. Hillsdale, NJ: Erlbaum.

Crawford, J. R., Deary, I. J., Allan, K. M., & Gustafsson, J.-E. (1998). Evaluating competing models of the relationship between inspection time and psychometric intelligence. *Intelligence*, *26*, 27–42.

Deary, I. J. (1993). Inspection time and WAIS-R IQ subtypes: a confirmatory factor analysis study. *Intelligence*, *17*, 223–236.

Deary, I. J., & Stough, C. (1996). Intelligence and inspection time: achievements, prospects, and problems. *American Psychologist*, *51*, 599–608.

Evans, G., & Nettelbeck, T. (1993). Inspection time: a flash mask to reduce apparent movement effects. *Personality and Individual Differences*, *15*, 91–94.

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica*, *26*, 107–129.

Hunter, J. E., & Schmidt, F. L. (1990). *Methods of meta-analysis: correcting error and bias in research findings*. London: SAGE Publications.

Jensen, A. R. (1998). *The G factor: the science of mental ability*. Westport, CT: Praeger Publishers/Greenwood Publishing Group.

Kranzler, J. H., & Jensen, A. R. (1989). Inspection time and intelligence: a met-analysis. *Intelligence*, *13*, 329–347.

Levy, P. (1992). Inspection time and its relation to intelligence: issues of measurement and meaning. *Personality and Individual Differences*, *13*, 987–1002.

McGeorge, P., Crawford, J. R., & Kelly, S. W. (1996). The relationship between WAIS-R abilities and speed of processing in a word identification task. *Intelligence*, *23*, 175–190.

McGrew, K. S. (1994). *Clinical interpretation of the Woodcock–Johnson Tests of Cognitive Ability—Revised*. Boston: Allyn & Bacon.

Mishkin, M., & Appenzeller, T. (1990). The anatomy of memory. In: R. R. Llinas (Ed.), *Readings from scientific American: the workings of the brain: development, memory, and perception*. New York: Freeman.

Nettelbeck, T. (1982). Inspection time: an index for intelligence? *Quarterly Journal of Experimental Psychology*, *34*, 299–312.

Nettelbeck, T. (1987). Inspection time and intelligence. In: P. A. Vernon (Ed.), *Speed of information processing and intelligence*. Norwood, NJ: Ablex.

Nettelbeck, T., Edwards, C., & Vreugedenhil, A. (1986). Inspection time and IQ: evidence for a mental speed–ability association. *Personality and Individual Differences*, *7*, 633–641.

Nettelbeck, T., & Kirby, N. H. (1983). Measures of timed performance and intelligence. *Intelligence*, *7*, 39–52.

Nettelbeck, T., & Rabbitt, P. M. A. (1992). Aging, cognitive performance, and mental speed. *Intelligence*, *16*, 189–205.

Vickers, D. (1979). *Decision processes in visual perception*. New York: Academic Press.

Vickers, D., & Smith, P. L. (1986). The rationale for the inspection time index. *Personality and Individual Differences*, *7*, 609–623.

Woodcock, R. W., & Johnson, M. B. (1989). *Woodcock–Johnson Psycho-Educational Battery—Revised*. Chicago: Riverside.