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Inspection time and speed of processing: Sex differences on perceptual speed but not IT

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Abstract

Inspection time (IT) is a pattern backward masking task that correlates with IQ. Recently, IT has been shown mainly to measure general speed of processing (Gs). Females outperform males on tests of Gs, for example Digit Symbol (DS) from the Wechsler scales. Combining data from several studies we examined whether there were sex differences in IT. $N = 653$ adults and children completed a standard IT task and DS. Expected female superiority on DS was confirmed but there were no sex differences on IT. Nonetheless, DS and IT correlated with each other. These results confirm the psychological complexity of IT and support suggestions that IT may be useful as a biomarker to monitor cognitive changes that accompany ageing.

Keywords: Inspection time; Perceptual speed; Digit symbol; Sex differences

1. Introduction

The issue of whether there are sex differences in intelligence or academic abilities is of interest to psychologists and lay people alike. Early investigations focussed on sex differences in general intelligence, as assessed by the intelligence quotient; and more recent investigations have examined sex

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differences on specific abilities in terms of both central tendency and variability. The consensus about IQ is that the existence or direction of any sex difference depends on the instrument used. This is because there are reliable differences favouring males on tests of general knowledge, mechanical reasoning, and mental rotations and favouring females on tests of language usage and perceptual speed, with other cognitive abilities showing no consistent sex differences (Feingold, 1992). The most comprehensive data to date come from a population study of 11-year old Scottish children collected in 1932 but analysed recently by Deary, Thorpe, Wilson, Starr, and Whalley (2003) who reported no sex difference in mean IQ but greater male variability such that males were over represented at the extremes of the IQ distribution. The IQ is a mixture measure of abilities and clearly a test could be designed to favour systematically either sex, or to produce no sex difference, on the global score (Mackintosh, 1998).

Tests of perceptual speed are a feature of all the major IQ batteries, the Digit Symbol (DS; also called Coding) from the Wechsler scales being perhaps the best known example. Sex differences on these type of tests consistently favour females. For example, Feingold (1992) reported that the overall mean sex difference for DS in the standardisations (1955 and 1981) of the WAIS and WAIS-R was $d = -0.34$.[1] In the same paper, the overall mean sex difference on clerical speed tests from the standardisations (1947, 1966, 1974, 1982) of the Differential Aptitude Tests was reported as $d = -0.48$. Similarly, Hedges and Nowell (1995) reported data on four very large scale studies (total $N = 127, 268$ adolescents and young adults) where the mean sex differences on perceptual speed tests were $d = -0.23$, -0.43, -0.23, and -0.21 for the four samples, respectively. The evidence clearly suggests a small-to-medium advantage for females on perceptual speed tests and we note here the prominent role of such tests in neuropsychological assessments and studies on cognitive decline in ageing.

Inspection time (IT) is a threshold measure of critical stimulus onset asynchrony (CSOA) for a two-alternative, visual pattern backward masking task which shows a corrected correlation with IQ of about -0.5 (Grudnik & Kranzler, 2001; Kranzler & Jensen, 1989; Nettelbeck, 1987). Recent work has converged on the conclusion that although IT is a measure of general speed of processing (Gs; Burns & Nettelbeck, 2003; Burns, Nettelbeck, & Cooper, 1999; Mackintosh & Bennett, 2002; O'Connor & Burns, 2003), it also loads on a general ability factor, that is, *g* (Burns & Nettelbeck, 2003; Crawford, Deary, Allan, & Gustafsson, 1998). These studies have used tests of perceptual speed as markers for Gs and the question therefore arises, are there sex differences in IT that reflect those seen in tests of perceptual speed? If this were not the case, it may enhance the utility of IT as a biological marker for cognitive decline during old age (see Nettelbeck & Wilson, 2004). Establishing whether there are sex differences on IT may also bear on the question of sex differences in *g* (see, for example, Nyborg, 2003).

Evidence on sex differences in IT is sparse. Luciano et al. (2001) reported a study on 184 pairs of homozygous and 206 pairs of heterozygous adolescent twins (age range 15–18 years). They reported a small but unreliable mean sex difference on IT with $d = -0.02$ (here again, the negative number represents better performance, that is, a shorter IT, for females). Arguably, however, the sample they used was not representative of the general population and the estimation procedure

[1] The convention of reporting differences favouring females as a negative number representing the ratio of the difference in means between males and females to the pooled standard deviation for both males and females is adopted here.

for IT was idiosyncratic. More recently, Codorniu-Raga and Vigil-Colet (2003) presented data on 222 adolescents (age range 11–14 years). The mean sex difference on IT was $d = 0.16$, favouring males. As with the Luciano et al. study, however, the nature of their sample renders conclusions on sex differences in IT for adults problematic. Moreover, their IT procedure used a so-called dynamic backward mask which has been criticised because it confounds the difficulty of the IT discrimination with the type of mask used (White, 1996).

Recent studies conducted in the Adelaide laboratory have used a uniform IT estimation procedure and have included samples widely disparate in age; and they have also included DS from the Wechsler scales as a test of perceptual speed. This paper, therefore, combines these data to examine whether there are sex differences on IT in the context of data on a test of perceptual speed for which sex differences are expected.

2. Method

2.1. Participants

The sample was 653 adults and children who participated in studies conducted at the Adelaide laboratory. The studies were classified as having sampled either: (i) adults from the general population; (ii) predominantly from students at the University of Adelaide; or, (iii) from among children at two Adelaide metropolitan schools. Table 1 gives details on these three groups of participants.

2.2. Apparatus and materials

2.2.1. Inspection time estimation

The following describes the standard IT estimation procedure used in all studies; details on durations of the warning cue and mask varied slightly across studies and depended on the vertical refresh rate of the monitor used. These minor variations have no effect on estimated IT.

IT stimuli were presented at a viewing distance of 1 m. The target figure consisted of two vertical lines, one subtending a visual angle of 2.1° and the other 2.5° and joined at the top by a horizontal line subtending an angle of 1.2°. The shorter line appeared on the left or right equiprobably. The target figure was preceded by a warning cue (small filled circle, 4 mm diameter) that lasted for approximately 520 ms. Following exposure of the target figure for the relevant

Table 1
Details for three samples: numbers of participants, sex, and age

Sample	*N*	Males	Females	Mean age (SD)[a]	Age range[a]
Adults from general population	267	169	98	34.7 (13.9)	18–78
Predominantly university students	218	73	145	20.7 (6.2)	16–51
School children	168	113	55	11.3 (1.8)	8–15
Total	653	355	298	24.0 (13.6)	8–78

[a] Age in years.

SOA, it was immediately replaced by a "flash" mask (Evans & Nettelbeck, 1993) of approximately 370 ms duration and consisting of two vertical lines subtending a visual angle of 3.3° and shaped as lightning bolts. The participant indicated on which side of the target figure the shorter line had appeared, by pressing the corresponding key on the response panel, or, for some studies, the corresponding button on the computer mouse.

Instructions emphasised accuracy, not speed of responding. What was required was first explained using diagrams, before demonstrating on the monitor with unmasked target stimuli. A series of practice trials with masked stimuli then ensured that participants understood what was involved. These required 10 correct trials out of 10 with SOA of approximately 835 ms, 10 correct trials out of 10 with SOA approximately 420 ms and nine correct trials out of 10 with SOA approximately 250 ms. All of the participants met these criteria. The estimation process began with SOA approximately 250 ms and followed an adaptive staircase algorithm (Wetherill & Levitt, 1965). The algorithm required three correct responses at any SOA before reducing the SOA by approximately 17 ms. When an incorrect response was made the SOA increased by approximately 17 ms. The average SOA was calculated over eight reversals of direction on the staircase, giving an estimate of the SOA with an associated probability of 79% of making a correct response. The IT task took approximately 10 min to administer.

2.3. Digit symbol

Versions of the DS task used were from the WISC-III, WAIS-R, or the WAIS-III and were administered according to the instruction in the respective manuals (these being near-identical). Number of items correct for DS were converted to scaled scores (Mean = 10, SD = 3) for most analyses because the time allowed varied according to which version was used, 90 s for the WAIS-R version and 120 s for the WISC-III and WAIS-III versions.

3. Results

Table 2 presents descriptive statistics for IT and DS. No difference across the three samples were found for DS scaled scores (Kruskal–Wallis test ($\chi^2(2) = 1.2, p = 0.55$)). However, consistent with developmental studies on IT which have shown longer IT for children and the elderly compared with young adults (Nettelbeck, 1987; Nettelbeck & Wilson, 1985), IT was related to age. Fig. 1 shows the relationship between IT and age; clearly there are nonlinear aspects to this relationship, which were modelled with a quadratic function ($\text{IT} = 85 - 1.58\,\text{Age} + 0.026\,\text{Age}^2$, $R^2 = 0.13$). When considering the combined sample, the residuals from fitting this model were used.

Consistent with previous reports, there was a difference in scaled scores for DS favouring females (combined sample $d = -0.42$; adults $d = -0.40$; university students $d = -0.44$; children $d = -0.57$). For IT, however, there were no such differences (combined sample $d = -0.06$; adults $d = -0.18$; university students $d = -0.02$; children $d = -0.10$). For the combined sample the statistical significance of the observed differences in Digit Symbol and IT were assessed by the Mann–Whitney test. For DS, $Z = 5.4$, $p < 0.001$ and for IT, $Z = 0.3$, $p = 0.76$. Of note also, male performance was more variable than female performance on both DS and IT but this difference

Table 2
Descriptive statistics, mean and standard deviation, for inspection time (IT) and digit symbol (DS) for three samples, total $N = 653$

	IT (SD)[a]	Digit symbol (SD)[b]
Adults from general population		
Males ($N = 169$)	65.8 (21.0)	10.9 (3.1)
Females ($N = 98$)	64.7 (18.1)	12.1 (2.9)
Total ($N = 267$)	65.4 (20.0)	11.4 (3.1)
Predominantly university students		
Males ($N = 73$)	64.1 (20.3)	10.9 (2.2)
Females ($N = 145$)	64.0 (15.7)	11.9 (2.3)
Total ($N = 218$)	64.0 (17.3)	11.6 (2.3)
School children		
Males ($N = 55$)	70.8 (17.9)	10.9 (3.2)
Females ($N = 113$)	73.2 (16.9)	12.6 (2.9)
Total ($N = 168$)	71.6 (17.6)	11.4 (3.2)
Combined samples		
Males ($N = 355$)	67.0 (20.1)	10.9 (3.0)
Females ($N = 298$)	66.0 (17.0)	12.1 (2.6)
Total ($N = 653$)	66.6 (18.7)	11.5 (2.9)

[a] Milliseconds.
[b] Scaled scores.

was only statistically significant for DS (Levene' test $F(1,651) = 6.6$, $p = 0.01$, and $F(1,651) = 2.9$, $p = 0.09$, for DS and IT, respectively). Finally, for the two samples where the correlation between items correct on DS and IT could be properly assessed (i.e., the adult and child samples, because the university students did not all complete the same version of DS), the correlations were $r = -0.33$, $p < 0.001$, $CI_{95} = [-0.43, -0.22]$ and $r = -0.48$, $p < 0.001$, $CI_{95} = [-0.59, -0.35]$, respectively.

4. Discussion

This paper sought to answer the question of whether there are sex differences on IT. The question is relevant for at least two reasons. First, IT measures general speed of processing (Gs), which is marked by tests of perpetual speed on which females outperform males; second, IT shares variance with *g*, even though IT is a simple perceptual task, and the question of sex differences on *g* is controversial.

The analyses presented here were for a subset of individuals who completed IT estimation in various studies at the Adelaide laboratory and also completed a version of the archetypal test of Gs, Digit Symbol (DS) from the Wechsler scales. Results of analyses were clear; while the expected sex differences on DS were found, there were no sex differences on mean IT that were either statistically significant, or of a size warranting theoretical interpretation. Expected correlations between IT and items correct on DS were observed, and males were more variable on both DS and IT (although not statistically significantly for the latter).

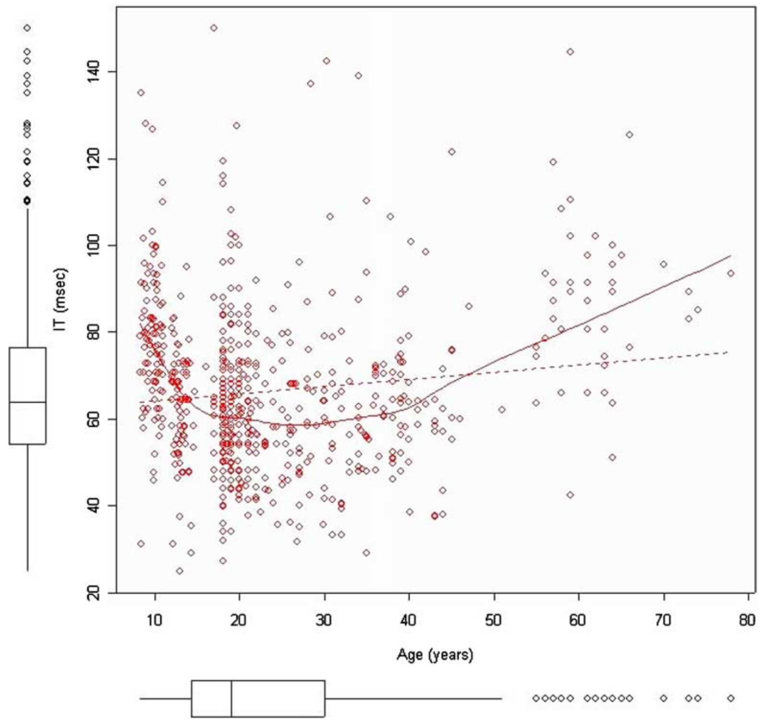

Fig. 1. Scatterplot of inspection time (IT) and age. Shown are the least squares regression line and a loess function. Along each axis are boxplots summarising the distribution of each variable.

Majeres (1983) summarised the literature on sex differences in DS and presented results from four experiments on manipulations of DS that were designed to elucidate the cause of the observed sex differences. One suggestion he made was that the sex difference in DS arises because of differences in comparison processes rather than in encoding processes. The comparison required in the IT task (i.e., which of two markedly different length lines is shorter) is trivially simple when no backward mask is used. Thus, because IT performance plausibly rests on speed of encoding, or detection of apparent movement inherent in the masking procedure (Burns, Nettelbeck, & McPherson, 2003), the current results are consistent with Majeres' suggestion. Clearly, DS and IT share common elements as evidenced by their correlation; but they both also possess independent variance that does not necessarily show sex differences.

Further interpretation of the main finding here—that is, no sex differences on mean IT—requires brief consideration of the nature of IT and its relationship with intelligence. Although recent studies have located IT within the Cattell–Horn–Carroll model of cognitive abilities (Burns & Nettelbeck, 2003), it also appears that IT has low communality when factor analysed with cognitive abilities batteries (Burns & Nettelbeck, 2003; O'Connor & Burns, 2003). Thus, variance in IT, which is not shared with cognitive abilities tests (measures of Gs like DS) and *g*, may be as high as 80%. The results here demonstrate that there is no sex difference on the majority of variance in IT, variance that presumably reflects non-cognitive processes (perception, attention, and so on, see Nettelbeck, 2001). We make the point once again that, although it has been widely regarded as a so-called elementary cognitive task, IT is psychologically complex (see also Deary et al., 2004).

Finally, results here are consistent with the possibility, raised by Nettelbeck and Wilson (2004) when considering their finding of no 'Flynn effect' for IT, that IT may be an attractive prospect as a biomarker to monitor cognitive changes that accompany ageing. Unlike DS, which has been used extensively in studies of cognitive decline, IT has now been shown to be stable across generations and to exhibit no sex differences.

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