Intelligence 37 (2009) 76–80

Contents lists available at ScienceDirect

Intelligence

Reversing the speed–IQ correlation: Intra-individual variability and attentional control in the inspection time paradigm

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ARTICLE INFO

Article history:
Received 23 April 2008
Received in revised form 1 August 2008
Accepted 1 August 2008
Available online 13 September 2008

Keywords:
Intelligence
IQ
Inspection time
Dual task
Attention
Intra-individual variability

ABSTRACT

Elementary cognitive tasks (ECTs) are simple tasks involving basic cognitive processes for which speed of performance typically correlates with IQ. Inspection time (IT) has the strongest IQ correlations and is considered critical evidence for neural speed underlying individual differences in intelligence. However, results from Bors et al. [Bors, D.A., Stokes, T.L., Forrin, B. & Hodder, S.L., (1999). Inspection Time and Intelligence: Practice, strategies, and attention. Intelligence, 27, 111–129.] suggest task consistency may underlie this shared variance. One possibility is that performance consistency reflects attentional mechanisms, as previous research has shown relationships between attentional control and cognitive performance. In study 1, participants were administered the Raven's Advanced Progressive Matrices and performed an alternative version of the IT task to measure individual trial-by-trial consistency expressed as the standard deviation of IT (ITSD). The alternative procedure yielded IT–IQ correlations similar to those obtained in previous studies and ITSD accounted for the IT–IQ variance. A second experiment tested whether ITSD measures attentional control, as participants simultaneously performed the IT task and an attention-demanding verbalization task. Under these conditions, high IQ participants performed worse on IT. These results suggest IT performance may reflect individual differences in attentional control and that this variable may account for the variance shared between IT and IQ.

Intelligence researchers have long considered processing speed to be a critical component of IQ (Eysenck, 1987; Jensen, 1993), often describing individual differences in cognitive performance across a range of tasks as a function of the inherent speed and efficiency of the nervous system (Eysenck, 1987; Jensen, 1993). Critical findings underlying these theories come from studies reporting negative correlations between reaction-times (RT) from elementary cognitive tasks (ECTs, typically timed tasks of very low difficulty said to reflect basic cognitive processes) and IQ (Vernon & Jensen, 1984). However, other studies suggest that variability on ECTs also tends to correlate with IQ (Jensen, 1992); moreover, others have reported findings suggesting individual differences in attentional control may give rise to variability on cognitive tasks (e.g. Colflesh & Conway, 2007; Conway, Cowan & Bunting, 2001). An intriguing possibility is that attentional control is one avenue through which individuals of high cognitive ability exhibit faster performance on ECTs. While this possibility does not dismiss the role of neural speed, it suggests these influences may be less direct. The principal aim of the present study is to determine whether individual differences in attentional control influence inspection time (IT)—the ECT considered most critical for speed theories of IQ.

Among ECTs, IT yields the highest correlations with IQ, shares variance with IQ that is independent of other ECTs (Petrill, Dasen, Thompson & Detterman, 2001), and is thought to measure perceptual speed (Deary & Stough, 1996, Mackintosh & Bennet, 2002). IT is a two-choice perceptual discrimination task in which participants attempt to determine which of two briefly presented parallel lines is shortest. The briefest stimulus duration, or stimulus onset asynchrony (SOA), at which a participant can achieve a given accuracy rate (typically between 70% and 95%) is the participant's

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0160-2896/$ – see front matter
doi:10.1016/j.intell.2008.08.002

threshold-IT. The task is central to speed theories of intelligence, given that motor movement does not confound estimated IT and that IT tends to yield the highest correlations with IQ among ECTs. In a recent meta-analysis featuring 90 studies, Grudnick and Kranzler (2001) report an uncorrected correlation of −.30 between IT and IQ (that increased to −.51 after correcting for artifacts of sampling and measurement error and restriction of range).

In contrast to neural efficiency theories, several researchers have suggested IT may reflect higher-level cognitive processes such as strategy use (Mackintosh, 1986) and attentiveness (e.g., Bors, Stokes, Forrin & Hodder, 1999; Stokes & Bors, 2001). The most frequently reported strategy described is an apparent-motion strategy (Mackintosh, 1986), where participants observe an apparent-motion caused by the appearance of the masking stimulus over the two differentially long lines. However, evidence suggests that variance between IT and IQ may be non-strategic, given that the correlation is strongest in samples not reporting strategy use (e.g., Egan & Deary, 1992; Grudnick & Kranzler, 2001), and that strategy users do not achieve higher IQ scores (MacKenzie & Bingham, 1985). Notably, use of strategies are determined by self-report, and investigators have not yet found an external source of validation that these participants are, in fact, performing the task differently.

Bors et al. (1999) argue that “attentiveness” or “participants' ability to remain focused trial by trial on the task” (p. 123), contributes to the IT–IQ correlation. Bors et al. demonstrated that accuracy at very long stimulus durations correlates with IQ, suggesting that low IQ participants sometimes perform poorly even on very easy trials. Such a finding suggests that these participants may perform the IT task inconsistently. Other studies of ECTs, have found that intra-individual variability (meaning consistence of performance for an individual, trial to trial), such as the standard deviation of reaction-time (RTSD), are often better predictors of intellectual performance than reaction-time means (Jensen, 1992). While Bors et al. did not report participants' standard deviations, the finding that low IQ participants fail on the easiest trials could result from lesser engagement in the task reflected in greater intra-individual variability.

An important consequence of intra-individual variability is that it tends to inflate mean values for many ECTs. When means are used to assess performance, those who perform inconsistently on ECTs will appear to perform poorly even if their best performances on some individual trials are very fast. A strong relationship between means and intra-individual variability complicates interpretation of the IQ–ECT correlations because it suggests plausible explanations involving third variables. For this reason it is critical to determine whether ECTs directly measure neural speed or other variables. Bors et al.'s findings suggest the possibility that performance on IT in part reflects attentional control. A growing body of literature on individual differences in working memory demonstrates that higher performing participants can more aptly allocate attention commensurate with instructions (e.g. Colflesh & Conway, 2007; Conway et al., 2001). For example, Conway et al. found that participants with higher working memory spans were less likely to hear their name in one ear when instructed to allocate attention to the other in a dichotic listening task. IT, like many attentional tasks, may in part reflect the ability to remain focused from trial to trial, and this ability should manifest as low intra-individual variability.

The aim of the following experiments is to test whether intra-individual variability in IT predicts IQ and to determine whether this variable reflects, at least in part, individual differences in attentional control. In Experiment 1 we test whether intra-individual variability accounts for the IT–IQ correlation by estimating IT with a stepwise procedure and computing the standard deviation of IT (ITSD). In Experiment 2 an auditory dual task is employed during estimation of IT to test whether high and low IQ participants differentially allocate attention.

1. Experiment 1

An alternative stimulus-selection procedure was developed for Experiment 1 that would maximize intra-individual variability. The procedure changed the SOA of the stimulus at every trial based on the accuracy of responses. Correct responses elicited briefer SOAs on subsequent trials and incorrect responses yielded longer SOAs.

1.1. Method

1.1.1. Participants

Participants were 77 Florida State University undergraduates receiving course credit for participation. All participants were at least 18 years old.

1.1.2. Materials

IT was estimated on a 19-inch CRT monitor with a refresh rate of 60 Hz, allowing SOAs approximating multiples of 17 ms. A l." by .75" pi-shaped stimulus was presented and participants attempted to determine which of its two parallel lines was shorter. The difference in the length of the lines occupied one-third the length of the stimulus. A fixation cross was displayed for 1 s in the center of the screen followed by the stimulus. A non-standard 100 ms backward mask (recommended by Simpson & Deary, 1997) immediately followed and participants had as much time as they desired to enter their response. Stimulus duration for each of 90 trials was determined by utilizing a one-up-one-down adaptive staircase procedure beginning with presentations of 102 ms. Correct responses resulted in a 17 ms. decrease in subsequent SOAs whereas incorrect responses resulted in a 17 ms. increase. For example, if a participant correctly answered the first four trials and missed the fifth and sixth, the SOAs on the first seven trials would be (in ms), 102, 85, 68, 51, 34, 51, 68. To prevent practice effects, training was limited to five trials at 102 ms.

1.1.3. Procedure

Participants were administered the short form of Set II of the Ravens Advanced Progressive Matrices (Bors & Stokes, 1998; Raven, 1965), which shares all the reliable variance with the original test. They were then situated at a comfortable distance in front of a computer monitor to estimate threshold IT.

1.2. Results

Threshold-IT was originally measured by determining which SOA at least 90% accuracy was achieved for each participant. At the suggestion of a reviewer a more conventional method was used in which threshold-IT was derived by