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Reaction time and intelligence: Comparing associations based on two response modes

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ABSTRACT

People who score highly on intelligence tests also tend to have faster and less variable reaction times. Effect size estimates for the reaction time–intelligence association are larger in samples that are more representative of the population. However, such samples have often been tested on a reaction time device that requires reading a number and processing its association with a specific response location (Cox, Huppert, & Whichelow, 1993). Here, we use this device and another reaction time device (Dykiert et al., 2010) that is similar, except that the responses require less processing; subjects simply press a button that is adjacent to the stimulus light. We focus on the possibility that lights as stimuli require less higher-order cognitive engagement than numbers, and then test whether parameters from these two tasks are highly correlated and similarly associated with age and higher cognitive abilities. Both tasks measured simple and choice reaction times and their intra-individual variation across trials. The parameters of the two tasks were very highly correlated and parameters from both tasks were similarly associated with age, social factors, and differences in higher cognitive abilities. The respective choice reaction time parameters from either task accounted for much of the age- and higher cognitive ability-associations of the other task's parameters. These findings are important in establishing that the effect sizes of higher cognitive ability associations with processing speed measures may be found when the processing demands are minimal.

1. Introduction

Reaction time has been used in the study of psychology since the nineteenth century (Cattell, 1890; Galton, 1890). Today, many types of reaction time task exist and are used in a variety of contexts and measured for their associations with various factors and in response to many manipulations. For example, using some examples from our own work, reaction times slow and become more variable with age (Deary & Der, 2005a; Der & Deary, 2006; Dykiert, Der, Starr, & Deary, 2012), correlate with measures of general fluid intelligence (Deary, Der, & Ford, 2001), and are associated with survival (Deary & Der, 2005b; Shipley, Der, Taylor, & Deary, 2006). In addition, reaction times are often used as an index of processing speed, which is seen by some as a fundamental factor in the age-related decline in various cognitive functions (Madden, 2001; Salthouse, 1996). Reaction times are also used in a number of other areas of study including medical research, psychopharmacology and experimental psychology (e.g., Strachan et al., 2001). In a large, age-homogeneous sample of people aged about 73 years, we found that processing speed—principally formed from reaction time parameters—wholly mediated the association between brain white matter integrity and general intelligence (Penke et al., 2012).

Reaction times are therefore a widespread, important and informative tool in the study of cognitive ability in psychology and other disciplines. It is important that the various reaction time tasks in use are valid and comparable with one another. Simple and choice reaction times are two useful indices used in many studies (e.g. Deary & Der, 2005a,b; Der & Deary, 2006; Dykiert et al., 2012; Shipley et al., 2006). Simple reaction time refers to the time taken to respond to a

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single stimulus, whereas choice reaction time refers to the time taken to make the correct response to one of a number of possible stimuli. With respect to choice reaction time, there can be a problem in comparing studies, in so far as the response modes can differ substantially between devices. We previously found this in attempting to compare age effects on reaction time parameters (Deary & Der, 2005a; Dykiert et al., 2012). Here, we principally address reaction time's associations with higher cognitive abilities.

The long history of studies that explore the associations of reaction times with psychometric intelligence test scores was motivated by an attempt to find something more fundamental about nervous system performance that might account for some of the variation in higher-level cognitive efficiency (Deary, 2000). Finding that relatively simple, possibly more tractable, reaction time indices were significantly associated with cognitive test scores contributed to refuting the suggestion that the latter were largely based on successful enculturation; and reaction time–intelligence associations seemed to offer hope that some of the variance in intelligence might be understood in simpler terms. We previously noted that such associations tended to be small in effect size (Deary, 2000, chapter 6). However, a large proportion of studies had included student samples, with likely attenuation of effect sizes. When a large population-representative sample of middle-aged people was studied, the effect size for the association between choice reaction time and intelligence was −.49 (Deary et al., 2001); people who scored better on the brief Alice Heim 4 Test of General Intelligence Part 1 tended to have faster choice reaction times.

Before we accept this effect size, it is worth considering the response mode of the reaction time device that was used (Cox, Huppert, & Whichelow, 1993; Deary et al., 2001). The device is represented in Fig. 1. Simple reaction time responses involve placing a finger lightly on the 0 button and pressing down as soon as a 0 appears on the liquid crystal display window. Choice reaction time responses involve placing the two index and middle fingers lightly on the buttons numbered 1 to 4, waiting to see which of the numbers 1, 2, 3, or 4 appears in the liquid crystal display window, and pressing the appropriate button as quickly as possible thereafter. This is arguably a more complex cognitive task than is desired in a reaction time task: the subject must process the number, translate the number into a relative position with respect to the four buttons, and then choose the appropriate button to press. It is possible, therefore, that this could be measuring individual differences in cognitive aspects of the process—the processing and translating to response position of the number—and this might explain this device's relatively high correlation with intelligence (and perhaps age) by comparison with other devices. The main possibility focussed upon here is that location-based lights as stimuli require less higher-order cognitive engagement than numbers.

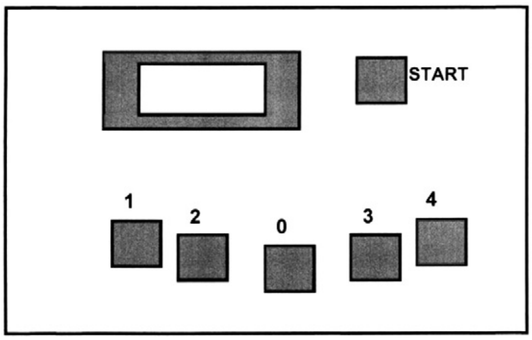

Fig. 1. Illustration of the top surface of the Numbers reaction time box.

The present study had the following aims. First, we devised a task that was as similar in structure and response demands as possible to the original numbers-based reaction time device (Cox et al., 1993), but that replaced the need to process numbers and link them to a location with a much more straightforward stimulus–response contingency using lights and their locations. Second, we compared the associations between the two reaction time indices provided by the new and old tests. Third, we compared the two reaction time devices' indices' correlations with higher-level cognitive ability test scores and age. Fourth, we tested whether the reaction time indices from one reaction time device could account for the other device's indices' correlations with age and higher cognitive ability.

2. Method

2.1. Participants

We tested 150 participants. Fifty were young adults aged between 18 and 25 years (mean = 20.5, SD = 2.6), fifty were middle-aged adults aged between 45 and 60 (mean = 53.7, SD = 4.9), and fifty were older adults aged between 61 and 80 (mean = 69.1, SD = 6.2). The large majority of participants in the young adult group aged 18–25 were students from the University of Edinburgh. Some of the older participants in this group were non-student residents from the City of Edinburgh. Participants in the middle-aged and older adult groups were residents from the city of Edinburgh. Some of these participants were recruited via a university volunteer database, and others via advertising around the city. None of the participants in the two older groups were students. The students received course credit for their participation and all other adults were paid a small honorarium for taking part. These are the same subjects who were used to test and validate the computer-based Deary–Liewald reaction time test (Deary, Liewald, & Nissan, 2011). Here, we use the cognitive test scores and numbers-based reaction time test data that were used in that publication. Their data from the lights-based reaction time device have not been published previously.

2.2. Cognitive ability tests

Participants were tested on three higher-level cognitive measures: the Digit–Symbol Coding subtest of the Wechsler Adult Intelligence Scale III (Wechsler, 1997); the Matrix Reasoning subtest of the Wechsler Abbreviated Scale of Intelligence (Psychological Corporation (The), 1999); and the Wechsler Test of Adult Reading (WTAR) (Psychological Corporation, 2001). Digit–Symbol Coding was included as a paper-and-pencil test of processing speed, Matrix Reasoning as a fluid-type (age-sensitive) cognitive test of abstract reasoning, and