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Common genetic influences on intelligence and auditory simple reaction time in a large Swedish sample

Guy Madison [a,*], Miriam A. Mosing [b,c], Karin J.H. Verweij [b], Nancy L. Pedersen [c], Fredrik Ullén [b]

[a] Department of Psychology, Umeå University, Umeå, Sweden
[b] Department of Neuroscience, Karolinska Institutet, Stockholm, Sweden
[c] Department of Medical Epidemiology and Biostatistics, Karolinska Institutet, Stockholm, Sweden

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ABSTRACT

Intelligence and cognitive ability have long been associated with chronometric performance measures, such as reaction time (RT), but few studies have investigated auditory RT in this context. The nature of this relationship is important for understanding the etiology and structure of intelligence. Here, we present a bivariate twin analysis of simple auditory RT and psychometric intelligence (measured by the Wiener Matrizen Test). The sample consisted of 1,816 complete twin pairs and 4623 singletons enrolled in the Swedish Twin Registry, who performed the tests online. The heritabilities were 0.54 and 0.21 for intelligence and RT, respectively, and the phenotypic correlation was −0.17, 47% of which was explained by common genetic variance. These results are comparable to those found for visual RT and for other cognitive tests, and add RT in the auditory modality to the small literature on common genetic influences across intelligence and other cognitive and chronometric variables.

1. Introduction

Cognitive ability has long been associated with various chronometric performance measures, such as reaction time (e.g., Galton, 1883; see also Jensen, 2002). This line of inquiry was initially concerned with the relation between psychometric intelligence (IQ) and simple reaction time (SRT) to visual or auditory stimuli, and was later extended to choice reaction time (CRT), reaction time variability, and measures of perceptual and cognitive speed. Reaction time is also associated with cognitive ageing (Deary & Der, 2005b; Fozard, Vercruyssen, Reynolds, Hancock, & Quilter, 1994) and motor timing (Holm, Ullén, & Madison, 2011). It may seem intuitively compelling that people who are able to respond faster are also brighter, but the nature of such a relationship remains obscure. Hick (1952) proposed a model based on information theory stating that reaction time be proportional to the number of bits of information that have to be processed in order to arrive at a decision, and that the time difference between a four-choice reaction task (2 bits of information) and a two-choice task (1 bit) should reflect the bit ratio. Individual differences in this entity would accordingly reflect differences in information processing speed. According to this theory, faster individuals could have a competitive edge by making a larger number of operations in the same amount of time, which may be increased by the fact that this time is often limited, as in a learning situation during a lecture. These ideas are discussed in depth by Jensen (1982, 2006) and Deary (2000), among others. Although Hick's quantitative predictions have not borne out empirically (Jensen, 1998; Rammsayer & Brandler, 2007), his model is of historical interest as an early attempt to explain relations between general cognitive ability and speed.

Another type of explanation is that more efficient central nervous system communication is characterized by less variability in neural activity, which results in more accurate and stable cognitive representations over time, something which could manifest itself both as higher cognitive performance and as lesser variability or higher temporal resolution in perceptual and motor tasks (Madison, Forsman, Blom, Karabanov, & Ullén, 2009; Rammsayer & Brandler, 2007; Ullén, Forsman, Blom, Karabanov, & Madison, 2008; Ullén, Söderlund, Kääriä, & Madison, 2012).

Regardless of the underlying mechanisms, a large empirical literature consistently indicates a chronometric-cognition relationship. For reviews, see Jensen (2006), Sheppard and Vernon (2008), and Rammsayer and Troche (2010). Two main conclusions can be drawn from this research. First, this relation is ubiquitous, and reflects an important phenomenon of great potential theoretical interest. It provides a window for observing the functional relationships between constructs that would seem to be theoretically unrelated, and hence an opportunity for experimentally exploring this relationship (Deary, 2001; Holm, Karampela, Ullén, & Madison, 2016; Holm, Ullén, & Madison, 2013;

* Corresponding author at: Umeå University, Department of Psychology, Behavioral Sciences Building, Mediagränd 14, A-123, SE-901 87 Umeå, Sweden.
E-mail address: guy.madison@umu.se (G. Madison).

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Holm et al., 2011; Karampela, Holm, & Madison, 2015; Ullén et al., 2012). Secondly, the chronometric-cognition relation varies substantially in strength across the plethora of different cognitive and chronometric tasks and methods (e.g., Jensen, 2006). It therefore remains important to replicate it in other samples and contexts, as well as with different modalities and methods, so as to map out the space of factors that influence it. Here, we attempt to assess the relationship between intelligence and auditory SRT, as well as the heritability of both constructs and their shared genetic influence.

Simple and choice reaction time are the chronometric tasks that have been most widely used, and tend to have exhibited the most consistent results (Jensen, 2006). SRT is also more stable than CRT with respect to ageing and sex (Fozard et al., 1994), and also with respect to development, as CRT but not SRT decreases from late adolescence to the early twenties (Deary & Der, 2005b). Previous research has reported phenotypic correlations between RT and IQ throughout the range from −0.05 to −0.5. For visual SRT, correlations of −0.20 (Larson, 1989), −0.31 (Deary, Der, & Ford, 2001), −0.26 (Jensen & Munro, 1979), and −0.53 (Thoma et al., 2006) have been reported. Very few studies have assessed phenotypic correlations between IQ and auditory RT, however. One reason may be that auditory choice reaction tasks with two, four, or even eight alternatives are more complex and difficult than their visual counterpart, because they typically require memorizing of sounds. As comparing simple and choice RT conditions is often an objective in RT studies, even simple auditory RT tasks may therefore be avoided. Yet, auditory RT and its relationships with other tasks should be of particular interest because humans are 45–60 ms faster to react to auditory than to visual stimuli, as reviewed by Niemi and Näätenen (1981). More recent studies confirm these figures, with 40 (Jaskowski, Jaroszyk, & Hojan-Jezierska, 1990) and 47 ms difference (Shelton & Kumar, 2010).

To our knowledge, only three studies consider both auditory RT and IQ. Agrawal and Kumar (1993) reported correlations of −0.40 for 50 males and −0.49 for 40 females, using Raven's SPM. Holm et al. (2011) found very small (non-significant) correlations between auditory SRT and Raven's SPM Plus among 112 university students (−0.050 and −0.065, for mean RT and RT variability) but substantially higher ones for CRT (−0.18) and CRT variability (−0.35), and Poon, Yu, and Chan (1986) found a −0.30 correlation between RT and Raven's SPM among 150 Chinese students.

A common chronometric-cognitive factor, as indicated by the literature above, suggests that individual differences in both traits are mediated by quite general mechanisms, possibly ones that are under genetic control. Literature reviews and meta-analyses of the heritability of general intelligence (*g*) point to an estimate between 0.7 and 0.8 for adults in Western societies (e.g., Bouchard, 2004; Panizzon et al., 2014). A meta-analysis of the heritability of chronometric variables found 12 relevant studies (Beaujean, 2005), and an overall heritability estimate of 0.30 for simpler and 0.52 for more complex chronometric tasks. Six of these reported common genetic influence between some chronometric and some cognitive variable, with genetic correlations in the range −0.4 to −1.0 and proportion common explained variance in the range 0.6–0.7. More recent studies not included in that meta-analysis report genetic correlations in the range −0.3 to −0.7 (Edmonds et al., 2008; Lee et al., 2012; Luciano et al., 2001; Luciano et al., 2004a; Luciano et al., 2005; Wainwright, Wright, Luciano, Geffen, & Martin, 2008) and proportion common explained variance in the range 0.2–1.0 (Luciano et al., 2001; Luciano et al., 2004a; Luciano et al., 2004b; Wainwright et al., 2008).

In conclusion, auditory RT is understudied compared to visual RT, and the shared genetic influence for auditory RT and IQ is as yet undocumented. Here, we obtain heritability estimates of simple auditory reaction time (SART) and assess its phenotypic and genetic correlations with IQ in a genetically informative sample that is much larger than those used in previous studies. We predict a phenotypic correlation in the range −0.2 to −0.5, and that more than half of the shared variance between the traits to be explained by common genetic influences, based on previous studies of the relationship between IQ and visual RT and other auditory tasks.

2. Methods

2.1. Participants

Data were sourced from a large cohort of 32,005 Swedish twins born between 1959 and 1985 (Lichtenstein et al., 2006), who were, during 2012 and 2013, invited to a web-based survey covering, among others, measures of IQ and auditory reaction time (see Ullén, Mosing, Holm, Eriksson, & Madison, 2014; Mosing, Pedersen, Madison, & Ullén, 2014 for further details about this survey). The total number of participants that started the survey was 11,543 and their age was 27–54 years (mean 40.7, SD 7.7).

Zygosity was determined based on self-rated intra-pair resemblance, a method shown to be >98% accurate when compared to zygosity status based on genotyping the twins registered at the Swedish Twin Registry (STR) (Lichtenstein et al., 2002). For further details on the STAGE cohort and zygosity determination in the Swedish Twin Registry see Lichtenstein et al. (2002, 2006). The present study received approval from the Regional Ethics Review Board in Stockholm (Dnr 2011/570-31/5, 2012/1107/32, 2012/2172-32).

2.2. Measures

The web survey took between 55 and 90 min to complete and contained a wide range of instruments and questions. Many of these are described in previous publications (e.g., Mosing et al., 2014). Measures of IQ and simple auditory reaction time (SART) were used in the present study.

The Wiener Matrizen Test (WMT) is a matrix-reasoning test similar to the Raven's Progressive Matrices (Formann & Piswanger, 1979). It was implemented in a Flash application that presented the pictures and recorded the participants' responses, and was discontinued after 25 min, according to the instructions for administration.

Reaction time was measured by software that ran in a plugin to the participant's web browser. This code was run in Shockwave, if installed on the participant's computer, or else in Adobe Flash. If none of these multimedia engines were installed and the participant declined to have them installed, the SART test was not run. The SART application issued a sound through the computer's headphones or loudspeaker, and registered the response on the space key of the computer keyboard. Each sound was preceded by a 1.5 to 3.5 s foreperiod, randomly varied from a rectangular distribution and starting from the previous response. Some systematic differences were observed between operating systems and software versions which were corrected for, thus decreasing the sample variance and reducing possible influences of the computer that participants happened to use for completing the survey. These methodological details are described in Madison, Woodley of Menie, and Sänger, 2016 (see Supplemental data, Appendix 1.1 and 1.2).

The SART trials had 10 and 25 runs, the median of which was subjected to analysis. The first trial was intended for training, but was used to estimate cross-trial reliability to 0.86. Within-trial split-half reliability was 0.95, based on the medians of the first and final 12 responses.

2.3. Statistical analyses

All analyses were conducted using maximum likelihood procedures in the statistical package Mx (Neale, Boker, Xie, & Maes, 2006), correcting for relatedness. Variables were analysed as standardized raw data. The classical twin design was used to determine the extent to which covariation between SART and IQ is due to overlapping genetic and/or overlapping environmental variance. In essence, the variance in a trait and the covariance between traits are decomposed into additive