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The relation between intelligence and reaction time in tasks with increasing cognitive load among athletes with intellectual impairment

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ABSTRACT

Intelligence has long been associated with chronometric performance measures, such as reaction time (RT); however, few studies have investigated this relation in humans at the lower end of the intelligence range. The purpose of this study is to examine the inter-relation between RT, and intelligence in the population of athletes with mild to moderate (IQ 40–75) intellectual impairment (II), according to the DSM-5 diagnostic criteria. IQ-scores were retrieved from the athlete-database, assessed prior to the study by means of the most recently standardized versions of the Stanford-Binet, Raven Progressive Matrices or Wechsler Intelligence Scales, i.e., WISC-V or WAIS-IV. Three RT tasks with increasing cognitive load were administered in this study. The sample consisted of 103 young individuals (32% females, mean age = 24.4 years, SD = 5.8) with II (mean IQ = 60.6, SD = 9.2), performing the tests prior to competing in the Global Games; the highest level of sport competition, organized by the International Federation for Intellectual Disability Sport. We tested whether IQ and RT were correlated in this sample by means of Pearson's correlations. Afterwards, a comparison sample of tertiary education students was recruited (n = 103; mean age = 21.1, SD = 2.4), whereby for each individual participant with II, a peer was selected on the basis of equal gender, practicing the same sport, and equal accumulated sport expertise. We focused on the possibility that RT tasks requiring higher cognitive load differentiate more between the samples. The 2 × 3 ANOVA demonstrated a significant group (athletes with II versus comparison group) by task (simple RT, choice RT, complex RT) interaction effect, indicating that the progression of RTs increase across the three tasks with increasing complexity, was more pronounced in the athletes with II than in the comparison sample. This is the first study investigating RT in a large sample of well-trained active individuals with II. It provides a benchmark for other studies and suggests that the impact of lower levels of intelligence on RT is most apparent in RT tasks with the highest cognitive load.

1. Introduction

Reaction times (RT) are a widespread, important and informative tool in the study of intelligence (Der & Deary, 2003; Lee & Chabris, 2013; Nissan, Liewald, & Deary, 2013). The relationship between RT and measures of intelligence has been studied since the second half of the 20th century (Jensen, 2006). Reviews of this research have indicated that there is a significant inverse correlation between measures of RT, inspection time and other measures of information processing time on the one hand; and general intelligence (or *g*) on the other hand (Vernon, 1983; Nettelbeck, Edwards, & Vreugdenhil, 1986; Deary, Der, & Ford, 2001; Sheppard & Vernon, 2008; McGrew, 2009a,b).

Many types of RT tasks exist (Cinaz, Vogt, Arnrich, & Tröster, 2012). Simple Reaction Time (SRT) refers to the time taken to respond to a single stimulus, and only one response option is available (Nissan, Liewald, & Deary, 2013). A task of this kind typically has a low *g*-loading (Schneider & McGrew, 2012). SRT does not require substantial cognitive effort; it is enough for the person being tested to simply indicate that the stimulus is perceived (Johnson & Deary, 2011). Nevertheless, there is a long history of researchers having interest in the study of the relation between SRT and intelligence; and faster RTs (i.e., shorter processing speed) in these very simple tasks are associated with complex reasoning (Schneider & McGrew, 2012). Choice RT tasks involve tasks with a higher *g*-loading, in which some minimal processing of information content is required; for example, in a four-choice RT-task, arrows may appear facing upwards, downwards, left or right; and the corresponding keyboard arrow must be chosen (Johnson & Deary, 2011).

Processing speed is a key area of intelligence, and the processing speed provides an indication of the rate at which tasks of a specified

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kind and difficulty are performed (McGrew, 2009a,b; Schneider & McGrew, 2012) which can be evaluated via RTs (Carroll, 1993). Nissan et al. (2013) demonstrated that people who score high on intelligence tests also tend to have faster RTs and less variance in RT performance. Deary, Der, & Ford (2001) showed that SRT indices were significantly inversely associated with cognitive test scores. The correlation between a four-choice RT and general intelligence in their study was −0.49 in a sample of 900 participants. Overall, the inverse relationship between intelligence and RT is clear (for reviews, see Jensen, 1998; Deary, 2000; Jensen, 2006); however, the strength of the relationship is debatable (Deary, Der, & Ford, 2001; Fry & Hale, 2000). Furthermore, most of the studies in this field of research comprised samples of young people at the higher end of the intelligence range (e.g., college and university students) (Der & Deary, 2003). The present study extends on the current knowledge by including a large sample of people with intellectual impairment, situated at the lower end of the intelligence range (IQ ≤ 75).

Intellectual impairment (II) is used through the remainder of this paper to denote deficits in intellectual functioning, which refers to general mental capacities, such as learning, problem solving, thinking abstractly etc., according to the American Association of Intellectual and Developmental Disabilities (AAIDD, 2010). According to the AAIDD's definition of intellectual disability, the individual should not only have II (IQ ≤ 75) to be clinically diagnosed, but two other criteria should also be met: (1) limitations in adaptive behavior, and (2) both manifested before the age of 18. More specifically, the sample included in the present investigation was diagnosed as having a mild to moderate II (IQ between 40 and 75). Various researchers included participants with II in their RT studies, and demonstrated that these individuals have slower RTs compared to peers without II, as well as more inter- and intra-individual variance in RT performance (Klotz, Johnson, Wu, Isaacs, & Gilbert, 2011; Koichi, Hideyuki, & Mitsuru, 2011; Kosinski, 2013;).

RT is also considered as a key factor determining performance in many sports. Sport expertise has been associated with improved RTs (Williams & Ericsson, 2005). However, it is not clear whether the RT of more experienced athletes is a product of their sport expertise or an artifact of individuals with naturally high processing speed being attracted to, and excelling in sport. To investigate this relationship between sport expertise and RT, a research design can be applied in which athletes/active individuals versus non-athletes/non-active individuals are compared (e.g., Khezri, Shahbazi, Kashan, & Pashabadi, 2011; Nuri, Shademehr, Moghaddam, & Ghotbi, 2012; Atan & Akyol, 2014). For example, the study by Nuri, Shadmehr, Moghaddam, and Ghotbi (2012) focused on comparing RTs between volleyball players and non-athletes, with the athlete-group displaying faster visual choice RTs and visual complex choice RTs than the non-athletes. An earlier study by Abourezk and Toole (1995) revealed that older active individuals reacted significantly faster than non-active controls. However, they only found differences for complex choice RT paradigms, but not on simple RT tests.

There is a gap within the literature to what extent sport expertise or specific interventions could improve the RT in athletes with II. The World Health Organization has highlighted being involved in sport and physical activity as a public health priority focus since 2004 (WHO, 2016). Specifically for the population of individuals with II, it is vital to be physically active, as Bartlo and Klein (2011) found moderate to strong evidence on the effectiveness of physical activity interventions on their balance, muscle strength, and overall health and quality of life. We are not aware of any studies investigating the effect of exercise on RT or on cognitive factors other than RT in athletes with II. Alternatively, a new body of literature is emerging investigating the impact of II on sport performance (Burns, 2015; Van Biesen, Mactavish, McCulloch, Lenaerts, & Vanlandewijck, 2016a). Van Biesen, Kerremans, Mactavish, and Vanlandewijck (2016b) investigated the relationship between cognition and tactical proficiency in well-trained table tennis players with II and they found that 18% of the variance in tactical proficiency was attributed to spatial visualization and simple RT. In another recent investigation with well-trained athletes with II from various types of sports (Van Biesen et al., 2016a) the cognitive skills component approach was used, i.e., focusing on the assessment of generic cognitive skills (i.e., outside the sport-specific context) that tap into the intrinsic cognitive demands of the sport. From that study it was concluded that athletes with II scored significantly below athletes without II on cognitive ability measures relevant to sport (i.e., Fluid Reasoning, Short-term Memory, Reaction and Decision Speed). However, there were large inter-individual differences, and about 2% of the II-athletes' sample obtained higher scores than the average score in the comparison group, most apparent in the purely speed-based tests, such as simple RT and complex RT.

In a study involving table tennis players with and without mild to moderate II, slower RTs and slower speed of upper limb were found for the table tennis players with II, and these measurements correlated positively with their table tennis proficiency levels (Van Biesen, Verellen, Meyer, Mactavish, Van de Vliet, & Vanlandewijck, 2010). In a more recent study, Van Biesen et al. (2016a) assessed RT in a large sample of well-trained athletes with and without mild to moderate II from various sports: track and field, swimming, table tennis and basketball. The RT measures included four pure speed-based measures, at the most basic level that did not require substantial cognitive effort. Significant differences in complex and simple RT were found between athletes with and without II. It is important to note that the athletes with II had significantly larger variability in RT performance. Schweizer (2001) provides a possible explanation, proposing that the speed advantage of people with higher intelligence test scores is more dominant when using more sensitive alternative RT tests requiring complex responses. This finding was confirmed in the large scale review performed by Lee and Chabris (2013). Combined data from 172 studies, with a total of 53,542 participants indicated that measures of intelligence were significantly positively correlated with RT and that for some measures this relationship became stronger as the complexity of the tasks increased. For the current project, a series of three RT paradigms will be used with increasing cognitive load, i.e., one pure speed-based test (simple reaction time), a choice RT test requiring decision speed and processing visual information and an adapted version of the Flanker test (Eriksen, 1995). The Flanker test has a higher *g*-loading compared to the two other RT tasks, as it is an example of a visual search task, in which participants need to indicate as rapidly as possible whether a given target item is present in a display, in which other items (called distracters) are present (Trick & Enns, 1998). During the Flanker task, stimuli present targets and distracters simultaneously, and the task is to ignore the distracters (response inhibition) and only respond to the targets. Since its introduction, the Flanker task has been widely used for studying attention, detection, distraction, executive control, and other aspects of cognition (McClean et al., 2013). The Flanker task also provides the opportunity to examine response time and response accuracy, as an inability to inhibit distracting stimuli leads to slower RTs and greater susceptibility to errors. Previous research has shown that individuals with II are characterized by medium to large inhibition deficits (Eriksen, 1995), and groups with higher scores on trait anxiety showed greater interference effects, a greater number of errors, and reduced efficiency than low trait anxiety groups (Gomez-Iniguez et al., 2014).

The purpose of this study is to investigate the inter-relation between intelligence, RT and sport expertise. The study aimed to (1) explore the relation between intelligence and RT in healthy, active individuals at the lower ends of the intelligence range; (2) compare the differences in RT performance between individuals with II and the comparison group; and (3) investigate differences in processing speed on three RT tasks with increasing cognitive load. The hypotheses are that (1) RT and intelligence are negatively correlated at the lower end of the intelligence range; (2) that the athletes in the comparison group score