Personality and Individual Differences 118 (2017) 11–16

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

On the relation between mental ability and speed of information processing in the Hick task: An analysis of behavioral and electrophysiological speed measures

Stefan J. Troche [a,*], Sarah Merks [b], Michael E. Houlihan [c], &, Thomas H. Rammsayer [b]

[a] Department of Psychology and Psychotherapy, University of Witten/Herdecke, Witten, Germany
[b] Department of Psychology, University of Bern, Bern, Switzerland
[c] Department of Psychology, St. Thomas University, Fredericton, New Brunswick, Canada

ARTICLE INFO

Article history:
Received 15 November 2016
Received in revised form 29 January 2017
Accepted 10 February 2017

ABSTRACT

Inspired by Robert Stelmack's research on the electrophysiological foundation of mental ability (MA), the present study investigated whether the well-established negative relation between reaction times (RTs) and MA in four conditions of the Hick task can be explained by faster stimulus classification and consolidation in working memory as measured by the P300 latency in the event-related potential. RTs of 113 female participants aged from 17 to 38 years increased with increasing number of response alternatives in the Hick task. Except for one condition, RTs were negatively and significantly related to MA but this relationship did not increase with task complexity. This pattern of results suggests that speed of response selection does not account for shorter RTs in individuals with higher than lower MA. Against our expectations, however, in none of the four conditions, P300 latency was related to MA. Thus, the negative association between RTs and MA cannot be explained in terms of faster stimulus evaluation and consolidation in working memory. As a tentative explanation of this lack of association, even the most complex condition was not demanding enough to require the inhibitory processes underlying the P300 component in a sufficient extent to reveal MA-related individual differences in P300 latency.

1. Introduction

Speed of information processing has been reported to be faster in individuals with higher compared to individuals with lower mental ability (MA) (see Jensen, 2006). This speed difference could be observed in reaction time (RT) measures (Jensen, 1982, 2006) but also in latencies of the event-related potential (ERP) (Stelmack & Houlihan, 1995). In the tradition of Bob Stelmack's life-time work in this field of research, the present study investigated MA-related speed differences in the Hick task and whether the P300 latency in the ERP, an index of the time required for classifying a stimulus independent of the response process (Beauchamp & Stelmack, 2006; Houlihan, Campbell, & Stelmack, 1994), helps to explain these speed differences.

The Hick task is one of the most frequently used tasks in experimental research on MA-related speed differences (Jensen, 2006). In the different conditions of this task, a visual imperative stimulus is presented in one out of one, two, four, or more possible positions. The participant's task is to respond to the stimulus as fast as possible. If there is only one position (0-bit condition), participants simply react to the appearance of the stimulus, whereas they have to make one or two decisions if the stimulus appears in one out of two (1-bit condition) or four (2-bit condition) possible positions, respectively. Hick's law (1952) holds that RT increases linearly with the number of binary decisions across conditions. Hence, the slope of the linear function is a measure of the speed with which a decision is made or, in other words, the correct response is selected. Roth's (1964) report that the slope is steeper in individuals with lower compared to individuals with higher MA led to an enormous number of studies on the relation between RT in the Hick task and MA (cf. Jensen, 1998, 2006). Meta-analyses revealed that MA is consistently, yet only modestly related to RTs in all conditions of the Hick task, while its relation to the slope of Hick's linear function, contrary to initial findings, seems to be rather weak and inconsistent (Neubauer, Riemann, Mayer, & Angleitner, 1997; Sheppard & Vernon, 2008). This pattern of results casts doubt on the notion that higher speed of decision making is responsible for the shorter RT in individuals with higher compared to individuals with lower MA. However, early studies searching for specific processes underlying the relation between MA and RT in the Hick task divided RT experimentally into decision time and movement time (Jensen & Munro, 1979) and found that decision time rather than movement time was related to MA. This result indicates that sensory rather than motor processes are involved in the relationship between MA and RT.

* Corresponding author at: University of Witten/Herdecke, Alfred-Herrhausen-Str. 44, D-58455 Witten, Germany.
E-mail address: stefan.troche@uni-wh.de (S.J. Troche).

http://dx.doi.org/10.1016/j.paid.2017.02.027
0191-8869/

An alternative approach to examine specific processes underlying the relation between MA and speed of information processing is the investigation of the ERP (for reviews see Stelmack & Beauchamp, 2001; Stelmack & Houlihan, 1995). The ERP is the electrophysiological response to a repeatedly presented stimulus event and is observed in the continuous electroencephalogram (EEG). The P300 component of the ERP is a prominent positive wave with a maximum peak at about 300 ms after stimulus onset. Although the functional meaning of the P300 latency is still controversial (e.g., Verleger, Jaśkowski, & Wascher, 2005), the most common hypothesis holds that it reflects the time needed for stimulus evaluation and updating of mental representations in working memory (Kutas, McCarthy, & Donchin, 1977; Polich, 2007). Furthermore, response selection and execution processes seem not to influence the P300 latency (Doucet & Stelmack, 2000; Kutas et al., 1977; Magliero, Bashore, Coles, & Donchin, 1984).

As demonstrated by numerous studies, but primarily by Stelmack and his colleagues, the latency of the P300 wave is negatively related to MA in the oddball paradigm (e.g., Bazana & Stelmack, 2002; Beauchamp & Stelmack, 2006; Fjell & Walhovd, 2003; Sculthorpe, Stelmack, & Campbell, 2009; Troche, Houlihan, Stelmack, & Rammsayer, 2009). Investigations using other tasks, however, revealed that this relationship depends on task characteristics and demands. For example, McGarry-Roberts, Stelmack, and Campbell (1992) used simple and choice reaction time tasks as well as linguistic processing tasks and found the P300 latency only in the latter tasks to be shorter in individuals with higher compared to lower MA. Houlihan, Stelmack, and Campbell (1998) reported even a positive correlation between MA and P300 latency in Sternberg's short-term memory scanning task, i.e. longer P300 latencies in individuals with higher compared to lower MA. Using an attentional-blink task, Troche, Indermühle, and Rammsayer (2012) observed shorter P300 latencies in individuals with higher compared to lower MA in easy conditions but longer P300 latencies in the most demanding conditions. Given that the Hick task is one of the most commonly used tasks to investigate MA-related differences in speed of information processing, it is surprising that, to the best of our knowledge, there are no studies that systematically investigated P300 latency across different Hick task conditions.

Therefore, the main goal of the present study was to investigate the relationship between MA and speed of information processing across four conditions of the Hick task as measured by RTs and P300 latencies. For this purpose, we employed a 0-bit, 1-bit, 2-bit, and 2.58-bit condition with one, two, four, and six response alternatives, respectively. We had the following hypotheses:

1. We expected mean RTs to increase linearly with the number of decisions to be made, while mean P300 latencies should not vary across task conditions due to their independence from processes of response selection and execution (Doucet & Stelmack, 2000).
2. Furthermore, we expected the well-known negative association between RTs and MA. This relationship should either
   a) become stronger from the 0-bit to the 2.58-bit condition as reported by previous studies (e.g., Rammsayer & Troche, 2016; Roth, 1964) or
   b) not vary as a function of Hick condition as suggested by Sheppard and Vernon's (2008) meta-analysis.

If hypothesis 2a was supported and the relation between RTs and MA becomes stronger from the 0-bit to the 2.58-bit condition, this result would indicate that primarily the time of decision making and/or response selection accounts for this relationship. P300 latency as a measure of speed of stimulus evaluation and updating mental representations in working memory (Beauchamp & Stelmack, 2006) might also be negatively related to MA. The relation between MA and RTs, however, should not (or only marginally) be explained by P300 latency.

Alternatively, if hypothesis 2b was supported the negative relation between RTs and MA does not increase with increasing number of response alternatives, speed of decision making and/or response selection cannot be considered the source of variance underlying the relationship between RTs and MA. Hence, speed of stimulus evaluation and, primarily, speed of updating mental representations in WM as measured by P300 latency might be a plausible candidate explaining the relationship between RTs and MA provided that P300 latency shows a negative association to MA.

2. Method

2.1. Participants

The sample consisted of 113 female undergraduate students ranging in age between 17 and 38 years. Mean age was 19.9 (SD = 2.7) years. All participants had normal or corrected-to-normal vision and hearing. None of them reported taking any centrally acting medication or suffering from neurological disorders. Participants were asked not to consume caffeine or nicotine 2 h and alcohol 24 h prior to the EEG recording. As reimbursement, they received either course credit and/or were paid CAD 10 per hour of participation. All participants were informed about the study protocol prior to testing and gave written informed consent. The local ethics committee had approved the study.

2.2. Assessment of psychometric intelligence

A short-version of Cattell's Culture Fair Test 20-R (CFT 20-R; Weiß, 2006) was used as a measure of MA. It comprises three subtests (series, classifications, and matrices) with 15 items and one subtest (topologies) with 11 items. Weiß (2006) reported a test-retest reliability of $r_{tt} = 0.85$ after two months. Testing of intelligence took place in individual or group testing sessions (max. 10 participants) one to 14 days before the experimental session. The four subtests were submitted to a principal component analysis. Component scores on the first unrotated component were used as estimators of the individual level of psychometric intelligence.

2.3. Hick task

2.3.1. Apparatus and stimuli

The present Hick reaction time task was adapted from Neubauer (1991). The visual stimuli were presented on a Dell Trinitron 19″ monitor with a screen resolution of 1024 × 768 pixel and a refresh rate of 75 Hz. Stimulus presentation and response recording was controlled by Eprime 2.0 and a Cedrus® response pad (RB-840; accuracy of ±1 ms). Stimuli were white-framed rectangles (1.8 cm × 1.35 cm) and white plus signs ("+", 0.6 cm) presented on a black background.

2.3.2. Procedure

The task consisted of a 0-bit, 1-bit, 2-bit, and 2.58-bit condition. Each condition contained 32 experimental trials preceded by written instructions and 10 practice trials. The conditions differed in the number of white-framed rectangles that were continuously presented on the monitor screen as depicted in panels a to d of Fig. 1. In each trial, a plus sign appeared in the center of one of the presented rectangles with a random delay of 1000 ms, 1333 ms, 1666 ms or 2000 ms. The participants' task was to respond to this plus sign as quick as possible (while avoiding errors) by pressing a response button. The response buttons were arranged in correspondence to the arrangement of the rectangles in the 2.58-bit condition (see panel d of Fig. 1). Responses were given with the index finger of the right hand in the 0-bit condition, the index fingers of the right or left hand in the 1-bit condition, the index or middle fingers of the right or left hand in the 2-bit condition, and with the index, middle-, or ring fingers of the right or left hand in the 2.58-bit condition. The plus sign remained on the screen until the response