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Reaction time and the dominant and non-dominant hands: an extension of Hick's Law

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Abstract

This study examined the difference between the dominant and non-dominant hands on four reaction time (RT) tasks. It was found that RT for both the dominant and non-dominant hands correlated with IQ at virtually the same magnitude. It was also found that the difference in mean RT between the dominant and non-dominant hands on a particular task was strongly correlated with the mean RT of each respective task. These results were interpreted in light of an extension of Hick's Law. The possibility that both cerebral hemispheres are capable of negotiating the cognitive demands of reaction time tasks is also discussed.

Keywords: Reaction time; Laterality; Intelligence; Hick's Law

1. Introduction

Hick's Law stipulates that: "RT increases linearly with the binary logarithm of the number of equally likely response alternatives in the [elementary cognitive task] ECT" (Jensen, 1998, p. 212). More simply, as the amount of information an individual is presented with increases, the amount of time it will take the subject to process the information will also increase. Thus, simple RTs are shorter than choice RTs. Based on several studies, comprising approximately 1850 subjects, Jensen (1998, p. 213) has estimated that the average RT at 0 bits of information is 335 ms. At 3 bits, the average RT increases to 439 ms. The slope of the linear regression of RT as a function of bits has been estimated to be 34 ms; thus, each bit of information added to a task above a simple RT task requires, on average, an extra 34 msec of information-processing. The significance of Hick's

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law in relation to intelligence is that there is also a positive correlation between the amount of bits involved in an RT task and the degree to which the RT task correlates with IQ (Jensen, 1998).

In one study (Vernon & Jensen, 1984), 106 subjects were administered a battery of eight RT tasks of varying complexity, operationally defined as average group RT (larger RT = greater complexity). Intelligence was equated with the '*g*' factor scores derived from the first principal component extracted from the Armed Services Vocational Aptitude Battery (ASVAB). The correlation between RT and g was found to be −0.47. Of particular interest was that the correlation of 0.98 between the mean latency of a processing task and the correlation between the individual RTs and the '*g*' factor. Thus, RT tasks associated with longer processing time were better correlates of *g*.

There is experimental evidence suggesting that, in right-handers, the left-hand should produce longer mean RTs to verbal stimuli. For instance, Marcel, Katz, and Smith (1974) presented verbal material (words and letters) to children (aged 6–8) tachistoscopically. Based on a reading proficiency test, the children were separated into two groups: poor and good readers. The verbal material was presented to either the left or right visual fields during separate trials. When the words were presented to the left visual field, the good readers, on average, identified correctly 7.9 words, whereas the poor readers identified 7.4. When the words were presented to the right visual field, the good readers identified 14.4 words, whereas the poor readers identified, on average, 11.3 words. The difference between the hemifields was calculated to be 6.5 words for the good readers and 3.9 words for the poor readers. Thus, good readers had greater asymmetry or lateralization than the poor readers. The effect proved to be even more pronounced for letters. When the letters were presented to the left visual field, the poor readers actually identified more letters than the good readers (61.2 vs. 51.8). For the right visual field, the good readers identified more letters than the poor readers (81.4 vs. 75.5). Thus, in accordance with the theory of hemispheric specialization, better performance was associated with greater performance asymmetry.

During the performance of an RT task with verbal content, the information would be expected to enter both hemispheres but should be processed primarily in the left hemisphere. Consequently, in order for the individual to make a response with the left-hand, the information would have to cross into the right-hemisphere first, which should take longer to execute, in comparison to responding with the right-hand, which is mediated by the left-hemisphere. Thus, if subjects had to complete verbal RT tasks with both their dominant and non-dominant hands, and the responses made with their non-dominant hand produced longer mean RTs than those produced from their dominant hand, one would expect the non-dominant hand RTs to correlate to a greater degree with g than the RTs from the dominant hand.

2. Method

2.1. Participants

A total of 81 participants (53 females, 28 males) were recruited from the University of Western Ontario's subject pool, which consisted primarily of first year university students. Participants participated for course credit. The average participant age was 20.1 (S.D. = 4.2). Average Full Scale IQ for the total sample was 110.1 (S.D. = 12.8).

2.2. Materials and procedure

Tasks were administered on an LCIII Macintosh Apple computer with a 13 inch b/w monitor. The four RT tasks were programmed on PsyScope, version 1.2.4.

1. Simple Reaction Time: The time between the presentation of a neutral stimulus and the release of the home key is estimated and used as the subjects score. This RT task was comprised of 40 items in total. The participant was asked to place the index finger of their dominant hand on the home key, in response to a fixation point in the center of the screen. The fixation point disappeared upon the participant placing his or her finger on the home key. After a random delay, a stimulus appeared in place of the fixation point, and the participant was instructed to lift their finger as quickly as possible when they saw the stimulus. For odd numbered trials, the subjects were asked to use their dominant index finger. For even numbered trials, the subjects were asked to use their non-dominant hand. A mean and S.D. was estimated for both hands (the same basic protocol stated here was used for all RT tasks, and, thus, will not be repeated).
2. Synonyms/Antonyms: The stimulus consists of two words on the monitor. The subject must decide if the words are synonymous or antonymous. There are 34 items in total. Seventeen of the pairs of words are antonymous to each other.
3. Sentence Verification [letter ordering]: The first stimulus consists of a logical statement (e.g. "A before B" or "B not after A"). The second stimulus consists of the two letters 'AB' or 'BA'. The subject must decide if the letters conform to the original statement. There are 34 items in total. Nineteen of the items consisted of a correct correspondence between the letter order and sentence.
4. Category Matching: The stimulus consists of two words. The first one is a category and the second an item. The subject must decide if the item is a member of the given category. There are 34 items in total. Items were selected evenly from eight different categories: coulour, gem, weapon, furniture, fruit, clothing, sport, and animal. Half of the items were matched.

Intelligence was estimated with the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981). administered in accordance with the instructions provided in the manual.

3. Results

As can be seen in Table 1, the correlations between dominant and non-dominant hands for the RT tasks were all very high, ranging in size from 0.87 to 0.93. To appreciate the relationship between the dominant and non-dominant hands, further, a Brinley plot of the means for all four tasks can be viewed in Fig. 1.

To determine if there were mean differences between the dominant and non-dominant hands, a series of *t*-test pairs were performed. For Simple reaction time, there was no statistically significant difference in performance between the dominant ($M = 276.57$) and non-dominant ($M = 275.45$) hands, t (79) = 0.40, n.s. For Synonym/Antonym reaction time, there was a statistically significant difference in favour of the non-dominant ($M = 1208.31$) over the dominant

Table 1
Correlations between the dominant and non-dominant hands on RT and PC loadings for the dominant and non dominant hands

	Correlation	Loading D[a]	Loading ND[b]
Simple	0.87	0.61	0.59
Syn/Ant	0.91	0.86	0.84
Sentence	0.90	0.83	0.85
Category	0.93	0.86	0.87

[a] Dominant hand.
[b] Non-dominant hand.

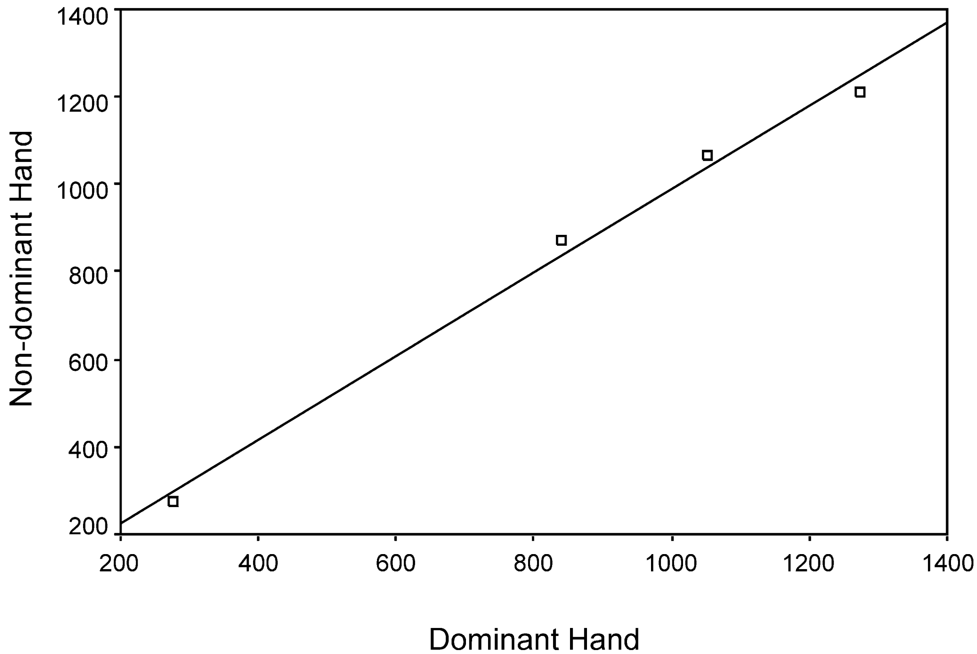

Fig. 1. Brinely plot of the means for the dominant and the non-dominant hands.

(M = 1272.16) hand, t (79) = 4.78, p < .05. There was also a statistically significant difference between the means for Sentence Verification, however, in contrast to Synonym/Antonym, it was in favour of the dominant hand (M = 839.07 vs M = 870.12), t (80) = −2.27, P < 0.05. Lastly, there was no statistically significant difference between the means for Category Matching (M = 1051.88 vs. 1066.11), t (79) = −1.63, n.s. Further analyses did not reveal an interaction based on sex.

Correlations were also computed to determine if RTs from the dominant and non-dominant hands correlated with intelligence differentially. To estimate dominant and non-dominant hand reaction time scores, factor scores were computed for each hand. These factor scores (rtg-dominant and rtg-non-dominant) were computed from the two general reaction time factors (PCA) that both hands produced (see Table 1). The correlation between rtg-dominant and FSIQ was r

(73) = −0.57, $P < 0.05$. The correlation between rtg-non-dominant and FSIQ was r (72) = −0.58, $P < 0.05$.

To estimate a mean reaction time for each of the four tasks (ie. mean processing time), the dominant and non-dominant hand mean RTs for each task were averaged. Although some controversy exists regarding the estimation of mean difference effect sizes (see Dunlop, Cortina, Vaslow, & Burke, 1996) for repeated measure designs, it was deemed appropriate to use the t-values in this study, because the sample sizes were the same for each task, and the correlations between the dominant and non-dominant hands were very similar for all four tasks (see Table 1). The correlation between the averaged RT for each task and the magnitude of the difference between the two hands was $r = 0.83$ (rho = 0.80; see Fig. 2).

4. Discussion

There were three main findings in this study: (1) there do not to appear to be any consistent differences in RT between the dominant and non-dominant hands in accordance with a left-hemisphere processing theory; (2) RTs from the dominant and non-dominant hands correlate with intelligence, equally well, (3) and the magnitude of the difference between the two hands correlates strongly with the average RT of the two hands combined.

The correlation between reaction time 'g' for the dominant hand and reaction time 'g' for the non-dominant hand was so high ($r = 0.96$) that one can infer that they were measuring the same construct: general speed of information-processing. Further, the correlations between both the dominant and non-dominant hands and FSIQ were virtually identical. The practical significance

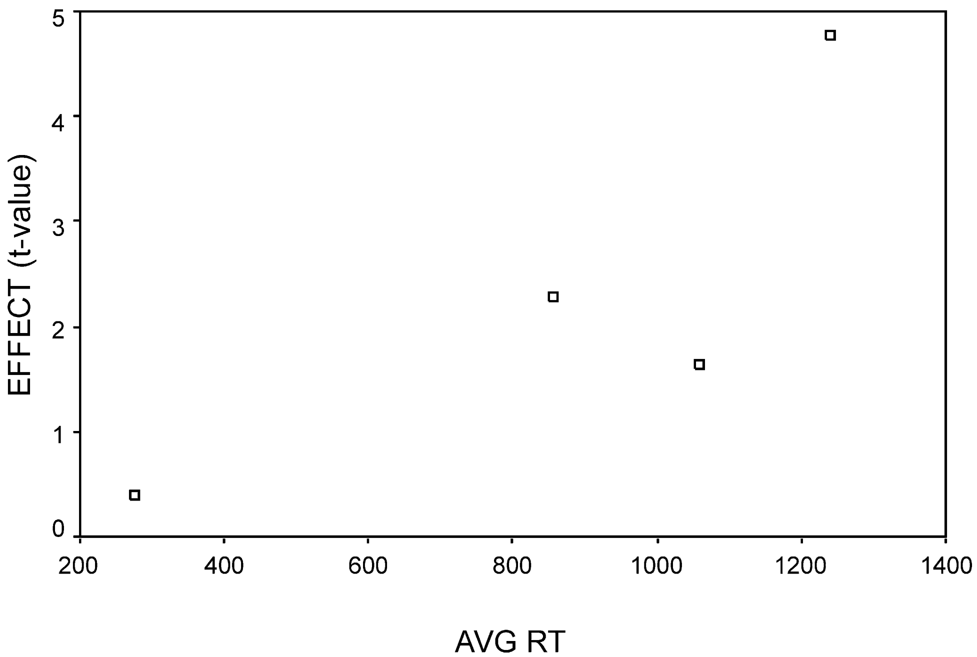

Fig. 2. Scatter plot of average RT and the magnitude of the difference between the dominant/nondominant hand.

of this finding is that, in the event that reaction time is ever validated as a diagnostic tool, clinicians will be able to feel confident asking a patient to use his or her non-dominant hand, in the event of impairment or injury to the dominant hand.

As a group, the RT differences between the dominant and non-dominant hands were not consistent with the hypothesis that the left hemisphere (dominant hand) would have an advantage over the non-dominant hand. Although no difference was expected between the dominant and non-dominant hands on the simple reaction time task, it was not expected that such a small difference would be found on the other three RT tasks, which were more cognitively demanding. Although statistically significant differences were found for Category Matching and Sentence Completion, the direction of the differences were not consistent with each other. That is, the non-dominant hand outperformed the dominant hand on Category Matching, whereas the dominant hand outperformed the non-dominant hand on Sentence Verification. However, the mean differences were very small, amounting to less than 65 ms for both tasks. These results confirm and extend the findings of Bisiach, Mini, Sterzi, and Vallar (1982), who also failed to find a consistent difference between the dominant and non-dominant hands on both simple and choice reaction time tasks. In Bisiach et al. (1982), the choice reaction time task was a relatively simple one, where the participants were required to press a switch if one dot appeared on the screen, and to refrain from pressing the switch, when two dots appeared on the screen. In the Bisiach et al. (1982) study, the mean reaction time for both hands combined on the choice reaction time was 414 ms. The present study had RT tasks that required more processing time (e.g. Category Matching mean for both hands combined was 1060.00 ms), but still failed to find any consistent differences in performance between the two hands. Thus, it appears that there is no language mediated difference between the dominant and non-dominant hands in reaction time, regardless of the cognitive demand (at least up to the 1000 plus millisecond level). This is puzzling, because three of the four RT tasks in this study had a decidedly linguistic component, which would lead one to believe that the left-hemisphere was processing the information required to make the various decisions that the tasks demanded. Thus, when the left hand was selected to execute the reaction time task, it was anticipated to take a certain number of milliseconds for the processed information to be relayed from the left-hemisphere to the right-hemisphere for execution.

The finding of a substantial positive correlation between the magnitude of standardized difference between the two hands (at the group level) and the mean of the two hands on a particular RT task is in line with the underlying notion of Hick's Law. That is, it appears that a cognitively more demanding RT task (as measured by mean RT) is associated with greater differential ability between the two hands, and, by inference, cerebral hemisphere processing. This is the first study to attempt to establish this relationship, consequently, replication is all the more important. It would be especially beneficial to attempt to replicate the effect with a larger number of RT tasks. Should the effect prove replicable, it may prove necessary to modify Hick's Law to incorporate these findings. That is, Hick's law specifies that the duration of a reaction time can be influenced by adding or subtracting "bits" of information. Although not disputing contradicting the "bits of information" claim, the findings of this study suggest that there may also be an association with differential hemispheric functioning.

From a neuropsychological perspective, the results of this study failed to support any general theory of language specialized hemispheric processing as a possible underlying mediator of RT behaviour. Using neuroimaging technology, it would be useful to determine which cerebral hemisphere(s) becomes active, when participants are required to perform a series of RT tasks, with both their dominant and non-dominant hands. Based on the results of this study, it would be hypothesized that both hemispheres can accommodate the cognitive demands of even relatively demanding RT tasks.

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