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# Is there any evidence of historical slowing of reaction time? No, unless we compare apples and oranges

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ABSTRACT

In this paper, we reconsider a tendency of historical slowing of simple reactions to visual stimuli declared by Woodley et al. (in press). We begin by reconstructing a pendulum similar to that used by Galton and question whether such an instrument could indeed be appropriate for purposes of RT measurement. Next, we screened the other studies used in Woodley's meta-analysis and note the important properties of these studies that make the RTs that they report incomparable to each other. We claim that there is no evidence of the trend of historical increase in RT after these differences between studies are taken into account. Overall, we conclude that any cross-study comparison of RTs is uninformative and cannot provide any evidence for speculating on the topic of historical change in intelligence.

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## 1. Introduction

The Victorians were 77 ms faster than modern Western populations in their simple reactions to visual stimuli. This is what Woodley, te Nijenhuis, and Murphy (in press) estimated in their meta-regression analysis of reaction time (RT) studies that were earlier reviewed by Silverman (2010). Based on this numerical estimate, as well as adopting results on RT-IQ correlation and the reliabilities of both from earlier studies, Woodley and colleagues concluded that the Victorians were cleverer than modern Western populations by 13.35 IQ points. The discovery was instantly picked up by mainstream media and produced active debates in the blogosphere.

However, what has been missed by Woodley and his colleagues is that simple RTs are extremely sensitive to properties of the visual stimuli presented to the participants, the equipment used for measurement, and the methods of primary analysis of the raw individual-level data (see Jensen (2006) for an exhaustive discussion on this matter). In this paper, we reconsider Galton's study and the studies initially selected by Silverman (2010) for purposes of comparison and question whether indeed the trend of historical increase in RTs postulated by Woodley and colleagues holds after at least some study properties are taken into account.

## 2. Is the pendulum an appropriate instrument for timing?

Our starting point is the question of whether Galton's pendulum-based apparatus could indeed provide precise estimates of RT. The reason to doubt this is that Galton's pendulum was released at 18° from vertical, which is quite a large swing for a physical pendulum. Given that the behavior of a real pendulum reproduces that of a mathematical pendulum only for small angles, it needs to be specially demonstrated that the motion of a pendulum with the properties described by Galton (1889a) can still be approximated by simple harmonic oscillations. If this is not the case and the motion of Galton's pendulum is close to separatrix (i.e., its curve in the phase space is not circular), the RTs registered by Galton would have had to be biased on certain intervals. In other words, theoretical RTs obtained for a mathematical pendulum and used by Galton for converting distances into time would underestimate true time taken by a physical pendulum to travel the respective distance. Hence, we begin by measuring actual movement times of a real pendulum with a release point of 18°. Next, we compare simple

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RTs obtained by such pendulum to RTs obtained in a computerized task.

### 2.1. Precision of a pendulum in time measurement

We constructed a pendulum similar to that used by Galton (1889a). This was a half-second pendulum (a pendulum with a period of 1 s so that each swing took 500 ms) that was always released at the angle of 18° from vertical. The leaden bob that was employed was 50 mm in diameter, 10 mm in depth, and weighted to approximately 220 g. An electric contact was placed on the bob to make measurement of its travel time possible. A pivot was fixed on a vertical backboard; round holes, located 1° apart, were made in this blackboard so that a needle, when placed in a given hole, stopped the pendulum in a known position.

The needle also had an electric contact. The electrical circuit had a voltage source of 1.5 V; release of the pendulum broke the circuit, and the contact between the bob and the needle placed in any particular hole closed the circuit again. The circuit output was connected to an audio input of a laptop computer.

A professional sound recording program was used for timing purposes with a sampling rate set at 192 kHz. The moment when the pendulum started moving (contact breaking) and its first contact with the needle (closure of contact) were recorded as peaks of a signal using the sound recording program. Thus, the time taken by the bob to travel between the release point and any given angle could be measured with high precision. However, it should be acknowledged that there might be a very small amount of deviation in the positions of the holes that could result in a slight reduction in precision of measurement.

For each final position of the pendulum, its travel time was recorded 10 times; the mean time and standard deviation were computed. Additionally, the theoretically expected time was computed by:

$$t = \arccos\left(\frac{l}{L}\right) \cdot \frac{T}{2\pi}, \quad (1)$$

where $l$ is the deviation from vertical at the final point, $L$ is the deviation from the vertical at the release point, and $T$ is the period.

Table 1 summarizes the times obtained from a real pendulum, the theoretically expected times, and the difference between the two. As can be seen, deviations of the real values from the theoretical ones are unsystematic and do not exceed 1.8 ms. Thus, our first conjecture that the trajectory of the real pendulum with the release angle of 18° deviated from that of a mathematical pendulum and that this would produce noticeable timing error was incorrect. A pendulum with the properties described by Galton could indeed be precise in time measurement, given that it had been appropriately adjusted and there were no constant lag between its release and stimulus presentation. On this latter issue, we believe that it is very unlikely, taking into account Galton's keenness for precise measurement, that there could be any noticeable discrepancy between the two events given that their simultaneous occurrence could be easily accommodated in this simple mechanical system.

**Table 1**
Movement time of a real pendulum and theoretical movement time of a mathematical pendulum.

| Angle from vertical | Mean movement time (SD) of a real pendulum | Theoretically expected time | Difference |
|---|---|---|---|
| 0 | 250.27 (1.134) | 250.00 | .27 |
| 1 | 240.73 (1.107) | 241.01 | −.28 |
| 2 | 233.78 (1.325) | 231.99 | 1.79 |
| 3 | 222.65 (1.113) | 222.91 | −.26 |
| 4 | 214.53 (.901) | 213.76 | .77 |
| 5 | 205.59 (1.166) | 204.49 | 1.1 |
| 6 | 195.25 (1.047) | 195.08 | .17 |
| 7 | 185.63 (.783) | 185.48 | .15 |
| 8 | 176.03 (.964) | 175.65 | .38 |
| 9 | 166.93 (1.476) | 165.52 | 1.41 |
| 10 | 156.42 (1.665) | 155.03 | 1.39 |
| 11 | 144.59 (.846) | 144.08 | 0.51 |
| 12 | 133.52 (.969) | 132.54 | .98 |

Note. Angle from vertical is that of the final position of the pendulum; time is given in milliseconds.

### 2.2. Pendulum- and computer-recorded RTs

We went a step further and rearranged our pendulum for actual reaction time measurement. This time, a black backboard separated a participant from an experimenter. On the participant's side, there were a white light emitting diode (LED) and a response key (Fig. 1A). The mechanical system was hidden on the experimenter's side, as shown in Fig. 1B. There could be two levels of luminance of the LED. The maximum luminance for the LED was 40 cd; however, lower luminance was achieved by introducing a 500-Ohm resistor to make the luminance similar in brightness to a similar stimulus shown on a computer screen. The participant saw not the LED itself, but a translucent round screen 10 mm in diameter. Release of the pendulum simultaneously closed the circuit and turned the LED on. The participant had to press a response key that had a descent distance of less than 0.4 mm. The bob of the pendulum had a metal plate to which a slender plastic strip with a thin magnet was attached. As the pendulum swung, the strip attached to it moved freely between the fixed plank with a graduated time scale and a movable bar parallel to it. This bar was connected to the response key via a system of levers so that at the moment of key pressure, the bar clamped on the strip. Thus, the response-position of the strip indicated the participant's RT.

For purposes of comparison, an E-prime experiment was also constructed with a round 10 mm stimulus presented on a laptop computer screen (refreshment rate 50 Hz). The stimulus was either a black circle on a white background or a white circle on a black background; the latter setting was the closest possible to stimulus presentation condition to our mechanical apparatus.

Since this empirical demonstration had solely illustrative purposes, we report the results here of only two participants, who were the authors of this study. Each participant performed eight sessions, with each session consisting of two series on the mechanical apparatus (two different brightness conditions) and two series on the computer (two different stimulus presentation conditions). The order of series was randomized across sessions. Each series included 10 trials; thus, mean RTs for each of the four conditions are based on 80 trials. Testing

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