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# Leaning to the Left Makes the Eiffel Tower Seem Smaller: Posture-Modulated Estimation

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## Abstract

In two experiments, we investigated whether body posture influences people's estimation of quantities. According to the mental-number-line theory, people mentally represent numbers along a line with smaller numbers on the left and larger numbers on the right. We hypothesized that surreptitiously making people lean to the right or to the left would affect their quantitative estimates. Participants answered estimation questions while standing on a Wii Balance Board. Posture was manipulated within subjects so that participants answered some questions while they leaned slightly to the left, some questions while they leaned slightly to the right, and some questions while they stood upright. Crucially, participants were not aware of this manipulation. Estimates were significantly smaller when participants leaned to the left than when they leaned to the right.

## Keywords

decision making, embodiment, posture, cognition, mental number line

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What information do people use to estimate something like the height of the Eiffel Tower? Perhaps they think of the height of another building and then mentally compare that building with the Eiffel Tower. This type of strategy is known as the anchoring-and-adjustment heuristic (Tversky & Kahneman, 1974). Although the anchoring process is well understood, less is known about the factors that affect adjustment. Researchers have recently theorized that bodily states provide important cues to higher cognitive processes (Barsalou, 2008). Consistent with this idea, results from several studies have shown that body posture influences memory retrieval and estimation (Bhalla & Proffitt, 1999; Dijkstra, Kaschak, & Zwaan, 2007; Riskind, 1983). In the present study, we examined whether posture affected magnitude estimates in a judgment task. According to the *mental-number-line theory* (Restle, 1970), people mentally represent magnitudes (symbolized by numbers) on a line with smaller numbers on the left and larger numbers on the right. Many studies have provided evidence that people associate their left hand (Dehaene, Bossini, & Giraux, 1993) and left visual field (Schwarz & Keus, 2004) with small numbers and their right hand and right visual field with large numbers. We hypothesized that people would make smaller estimates when they leaned slightly to the left than they would when they leaned slightly to the right. Moreover, we hypothesized that people would do so even when they thought they were standing upright.

## Experiment 1

### *Participants*

Thirty-three undergraduate psychology students (9 male, 24 female; ages 18–27) participated in this study for course credit. All participants were right-handed. They were randomly assigned to one of six lists, which differed with respect to the order of the postures and the order in which estimation questions were presented.

### *Apparatus*

We used the Wii Balance Board to manipulate and measure participants' center of pressure (COP). COP is a measure of body posture and balance; measurements of COP represent the distribution of pressure on a two-dimensional surface, such as a force platform. The Wii Balance Board produces measurements of COP that are as reliable and valid as those produced by expensive laboratory-grade force platforms (Clark et al., 2010). We used custom software to record event-related changes in COP.

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### *Materials and procedure*

Participants answered 39 estimation questions (see Table S1 in the Supplemental Material available online) while standing on the balance board. They were told that they probably did not know the correct answers to the questions, that they therefore would have to provide estimates, and that they had to stand upright during the experiment. To ensure that participants' neutral body posture was consistent with the center of a fixation cross, we calibrated the balance board for each participant before each experimental session. To help participants maintain their position, we displayed their COP on a computer screen. Participants were instructed to make sure their COP remained within a circle in the middle of crosshairs displayed on the screen. When participants' COP strayed from this circle, the screen displayed a warning signal, which prompted them to recenter their COP. We recorded the *x*- and *y*-coordinates of the COP continuously throughout each trial.

We wanted participants to think that they were standing upright during the experiment. The COP displayed on the computer screen always indicated that participants were standing upright, but we surreptitiously manipulated participants' body posture so that they were leaning slightly to the left, leaning slightly to the right, or standing upright. The magnitude of displacement was 0.77, approximating a 2% change in the proportion of weight on the left and right sensors of the board. We included a 1-min balance game before each change in posture to ensure that participants would remain unaware that their posture was being manipulated.

The estimation questions appeared on the screen above the COP and were presented in three blocks of 13 questions each. We presented the questions in a set, random order to half of the participants and reversed this order for the other half of the participants. All participants completed one block in each of the three postures; a third of the participants started in the left-leaning posture, a third started in the upright posture, and a third started in the right-leaning posture. The order of questions and the order of body postures were counterbalanced across participants. Participants reported their answers orally, and the experimenter wrote them down. The experimenter sat in the same room as the participants but could not be seen by them during the task. Each time a participant answered a question, the experimenter used a remote control to advance the screen to the next question. Afterward, participants filled out a form on which they indicated for each estimation question whether their answer had been an estimate or they had known the answer for sure. None of the participants indicated awareness of the fact that their body posture had been manipulated.

### *Results*

Although some participants claimed that they knew the answers to some of the questions, they did not answer those questions correctly. We therefore assumed that all answers were estimations. To compare data across questions, we *z*-transformed our data separately for each question. We then calculated a mean *z* score for each participant across the questions for each of the three posture conditions (left-leaning, upright, and right-leaning), which resulted in 33 *z* scores (11 per condition). In an initial analysis, we submitted these data to a 3 (posture: left-leaning, upright, right-leaning) × 3 (posture order: left-leaning first, upright first, right-leaning first) × 2 (question order: random, reversed) mixed analysis of variance (ANOVA), with posture entered as a within-subjects factor and the two orders entered as between-subjects factors. Because the two order factors did not interact with posture, we omitted them from our final analysis (Pollatsek & Well, 1995). We found a significant main effect of posture, $F(2, 64) = 3.38$, $p < .05$, $\eta^2 = .10$. As predicted, within-subjects contrast analyses showed that participants gave smaller estimates while leaning to the left than they did while leaning to the right, $F(1, 32) = 4.42$, $p < .05$, $\eta^2 = .12$. They also gave smaller estimates while leaning to the left than they did while standing upright, $F(1, 32) = 6.45$, $p < .05$, $\eta^2 = .17$. However, the magnitudes of estimates made while participants were standing upright and while participants were leaning to the right did not differ ($F < 1$; see Fig. 1).

The estimates assessed in this experiment were estimations of diverse dimensions (e.g., the height of a building, the population of a city, the percentage of alcohol in a beverage) made using diverse scales (e.g., centimeters, kilometers). In Experiment 2, we used a single dimension (quantities expressed

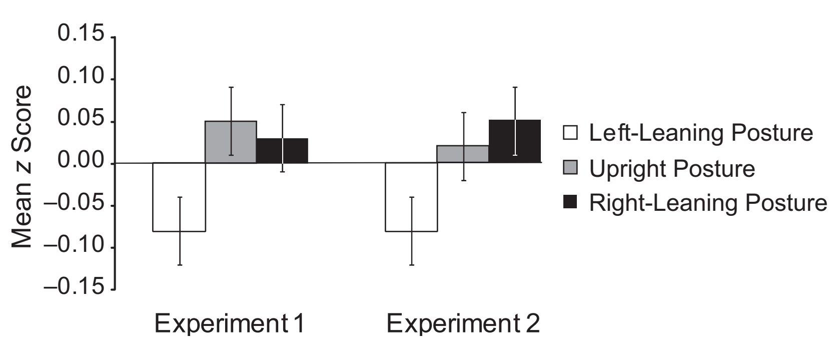


**Fig. 1.** Mean z scores (±1 *SE*) for participants' estimates in the three posture conditions in Experiment 1 (*N* = 33) and Experiment 2 (*N* = 58).

as natural numbers) with a restricted range (from 1 to 10). Participants were asked, for example, how many number-one hits Michael Jackson had in The Netherlands (6) and how many grandchildren Queen Beatrix of The Netherlands has (8).

## Experiment 2

### Participants

Fifty-eight undergraduate students (15 male, 43 female; ages 18–29) participated in this study for course credit or €3. As in Experiment 1, all participants were right-handed and were randomly assigned to one of six lists.

### Materials and procedure

The materials and procedure used in Experiment 2 were the same as those used in Experiment 1, with the exception of the estimation questions. In Experiment 2, the correct answers to all 39 questions (see Table S2 in the Supplemental Material) were numbers from 1 to 10. Participants were told that all of their estimates had to fall within this range. No participants reported awareness of the manipulation of their posture.

### Results

All participants were able to answer all of the estimation questions, and none of the participants claimed to know the real answer to any of the questions. As in Experiment 1, we transformed our data to *z* scores and calculated a mean *z* score for each participant in each of the three posture conditions. We then performed a 3 (posture: left-leaning, upright, right-leaning) × 3 (posture order: left-leaning first, upright first, right-leaning first) × 2 (question order: random, reversed) mixed ANOVA. The two order factors interacted significantly with posture, but given that our purpose in conducting this analysis was to reduce error variance, and given that the order factors were theoretically irrelevant, we do not report effects involving these factors (Pollatsek & Well, 1995). There was a significant main effect of posture, $F(2, 106) = 4.05$, $p < .025$, $\eta^2 = .07$. As in Experiment 1, a within-subjects contrast analysis showed that participants gave smaller estimates while leaning to the left than they did while leaning to the right, $F(1, 53) = 6.74$, $p < .015$, $\eta^2 = .11$, and that participants gave smaller estimates while leaning to the left than they did while standing upright, $F(1, 53) = 6.96$, $p < .015$, $\eta^2 = .12$. The magnitudes of estimates made while participants were standing upright and while they were leaning to the right did not differ ($F < 1$; see Fig. 1).

## General Discussion

Body posture influences quantitative estimates. We predicted that people would make smaller estimates while leaning slightly to the left than they would while leaning slightly to the right, and this prediction was borne out by our results. Remarkably, our manipulations of posture influenced participants' estimations even though participants were unaware of their true posture. According to the mental-number-line theory, people mentally represent numbers on a line with smaller numbers on the left side and larger numbers on the right side (Restle, 1970). Presumably, making an estimation involves retrieving instances from memory, and such instances function as anchors (Tversky & Kahneman, 1974). Leaning to the left should therefore make smaller numbers more accessible than larger numbers, and leaning to the right should make larger numbers more accessible than smaller numbers.

In both experiments, results for the upright position were statistically identical to results for the right-leaning position. The fact that we used each participant's neutral position as his or her upright position might have contributed to this result. Given that all participants were right-handed, their neutral stance may already have been right of center. There is some evidence to suggest that when people attempt to balance themselves, they show a subtle directional bias favoring whichever hip is on the same side as their dominant hand (Balasubramaniam & Turvey, 2000). This potential bias toward the right may have diminished or even eliminated differences between estimations made in the upright and right-leaning conditions in our experiments. This account is only speculative, but researchers could test it in future studies by examining left-handed participants. It should also be noted that in another study on the mental number line in which participants completed a task in central, left-oriented, and right-oriented conditions, performance in the central condition was found not to fall midway between performance in the left- and right-oriented conditions, but rather to align with performance in one of the two directional conditions (Nicholls & McIlroy, 2010).

We did not compare the estimates given by the participants with the actual magnitudes of the quantities they estimated because we were interested in relative differences as a function of body posture. However, in Experiment 1, participants who were leaning slightly to the left judged the Eiffel Tower to be 12 m shorter than did participants who were leaning slightly to the right.

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#### Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

#### Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

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