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Stand by Your Stroop: Standing Up Enhances Selective Attention and Cognitive Control

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It is rarely recognized that people are dual taskers all the time. They must simultaneously control body posture and whatever cognitive task they are engaged in at the moment. Even a common position like standing engages complex attentional and physiological mechanisms (more than the usual default sitting position does; e.g., Kerr, Condon, & McDonald, 1985; Lajoie, Teasdale, Bard, & Fleury, 1993; for a review, see Samuel, Solomon, & Mohan, 2015; Woollacott & Shumway-Cook, 2002). The posture-attention bond has been investigated mainly with the goal of determining the effect of attention and cognition on the maintenance of posture. In this study, we examined the reverse causal link: the effect of standing as opposed to sitting on the selectivity of attention. To gauge the selectivity of attention, we used psychology's classic tool, the Stroop effect: the larger the Stroop effect, the greater the failure of selective attention to the target attribute.

During standing, multiple muscles must be tonically active because the line of gravity falls slightly in front of the knees and ankles, so that "no one stands absolutely still" (Samuel et al., 2015, p. 72). Attention must be continuously engaged to maintain this posture because there is no such thing as quiet standing. Given that "stance postural control [is] attentionally demanding" (Woollacott & Shumway-Cook, 2002, p. 2), how do the extra attentional demands affect performance in a concurrent cognitive task? The scant literature on this question (mainly in the domains of gerontology and physiology, usually with a pragmatic purpose) presents conflicting results: Some studies show that standing impairs performance (e.g., Kerr et al., 1985), whereas other researchers report that standing improves performance (e.g., Hazamy et al., 2017). Mainstream cognitive research can provide a clue given the possibility that the continuous maintenance of the standing posture imposes a potentially stressful load on the organism. Now it has been shown that the selectivity of attention improves under stress (e.g., Chajut & Algom, 2003) and load (e.g., Lavie, Hirst, De Fockert, & Viding, 2004); recent studies show that stress and load share the same physiological and attentional mechanism (e.g., Sato, Takenaka, & Kawahara, 2012; Tiferet-Dweck et al., 2016).

One must be circumspect, though, when considering the effect of standing-induced stress on selective attention: In general, if a secondary task (e.g., maintenance of posture) is made more difficult, it decreases performance on a cognitively demanding primary task. Stress indeed impairs performance in tasks of divided attention, integration of information, or decision making (e.g., Keinan, 1987). However, selective attention is a notable exception: It has been repeatedly shown that stress or load (or both) actually improves the selectivity of attention.

In a study that addresses this issue, Koch, Holland, Hengstler, and van Knippenberg (2009) had participants perform a Stroop task after stepping backward or forward (with a constant distance separating participants from the stimuli). The Stroop effect was smaller after they stepped backward, probably because of the stress or extra vigilance fostered when walking backward. This stress was conducive to enhanced selectivity of attention, as expressed in a smaller Stroop effect. Given the results obtained by Koch et al. and the likelihood that standing, as opposed to sitting, entails extra attentional load and stress, we expected that standing would be conducive to a smaller Stroop effect.

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Method

All participants in all three studies had normal or corrected-to-normal vision, and none reported color blindness.

Experiment 1

Participants were Tel Aviv University undergraduate students (N = 17; mean age = 23 years, age range = 19–27 years). This number of participants provided .61 power to find a medium-size effect. The stimuli were the color words "RED," "GREEN," "BLUE," and "BROWN" combined factorially with the corresponding print colors. The stimuli were generated in Microsoft Word (in 24-point Miriam, a Hebrew typeface) on a PC and displayed on a light gray background on a 14-in. color monitor (resolution = 800 × 600 pixels). Viewed from a distance of approximately 60 cm, single words subtended 0.57° of visual angle in height and between 1.33° and 5.16° of visual angle in width. This constant distance was preserved across standing and sitting. During both conditions—sitting and standing—the participants were presented with 72 color-word Stroop stimuli, half of which were congruent and half of which were incongruent. The order of testing between sitting and standing was counterbalanced in a random fashion across participants. The participants responded by speaking the name of the print color in which the words appeared into a microphone (HPX-8 headset; Teac, Tokyo, Japan).

Experiment 2

Participants were Tel Aviv University undergraduate students (N = 16; mean age = 24.2 years, age range = 19–26). In this experiment, the stimuli were arrows pointing upward or downward, each placed in the top position (3 cm above the fixation point at the center of a 12- × 8-cm rectangle) or in the bottom position (3 cm below the fixation point at the center of an identically sized rectangle). The task consisted of deciding the direction of the arrow while ignoring spatial position. There were 32 trials, half of which were congruent (e.g., an upward pointing arrow in the top position) and half of which were incongruent. The participants responded by pressing one of a pair of lateralized keys on a computer keyboard; the response to which the keys were mapped was counterbalanced across participants.

Experiment 3

Participants were Ariel University undergraduate students (N = 50; mean age = 26.1 years, age range = 19–32 years). The stimuli and design were the same as in Experiment 1. Special care was taken to remove all demand characteristics (in particular, all the experimenters were blind to the hypothesis). Increasing the number of participants to 50 provided a power of .92 to detect a medium-sized effect. This is very high power, which means that there was a very high probability of detecting any existing effect. The analysis was based on correct responses only (98% in Experiment 1, 97.2% in Experiment 2, and 97.5% in Experiment 3); we also removed responses deviating from each participant's mean response time (RT) by more than 2.5 *SD* (3.8%).

Results

Order (standing, sitting) was tested in each experiment but was not significant and did not interact with posture and congruity in each analysis of variance (ANOVA; Fs < 1 in all cases). In Experiments 1 and 2, we recorded significant Stroop effects in both the standing and sitting conditions. The mean RTs for color naming in the sitting condition of Experiment 1 were 785 ms (95% confidence interval, CI = [740.08, 829.92]) when the stimuli were congruent and 892 ms (95% CI = [852.45, 931.55]) when the stimuli were incongruent, $t(16)$ = 8.689, $p < .01$, Cohen's d = 2.147. The mean RTs for color naming in the standing condition of Experiment 1 were 785 ms (95% CI = [743.94, 826.06]) when the stimuli were congruent, and 861 ms (95% CI = [832.23, 889.77]) when the stimuli were incongruent, $t(16)$ = 6.687, $p < .01$, d = 1.857. In the case of judgments of arrow direction, the mean RTs in the sitting condition of Experiment 2 were 523 ms (95% CI = [472.52, 573.48]) when the stimuli were congruent and 625 ms (95% CI = [567.91, 682.09]) when the stimuli were incongruent, $t(15)$ = 2.728, $p < .01$, d = 0.683. The mean RTs for arrow-direction judgment in the standing condition of Experiment 2 were 572 ms (95% CI = [523.46, 620.54]) when the stimuli were congruent and 603 ms (95% CI = [565.69, 640.31]) when the stimuli were incongruent, $t(15)$ = 2.207, $p < .05$, d = 0.59.

The most revealing feature of the data was the decrease in the Stroop effect when participants were standing. For color naming, the difference of 32 ms favoring standing was confirmed by the interaction of posture and congruity, $F(1, 16) = 5.701$, $p = .03$, η_p^2 = .263. For arrow direction, the difference of 71.54 ms favoring standing was confirmed by the interaction of posture and congruity, $F(1, 15) = 4.062$, $p = .062$, η_p^2 = .213.

The results for Experiment 3 are presented in Figure 1. Overall, the responses were faster when participants were standing than when they were sitting, $F(1, 49) = 7.33$,

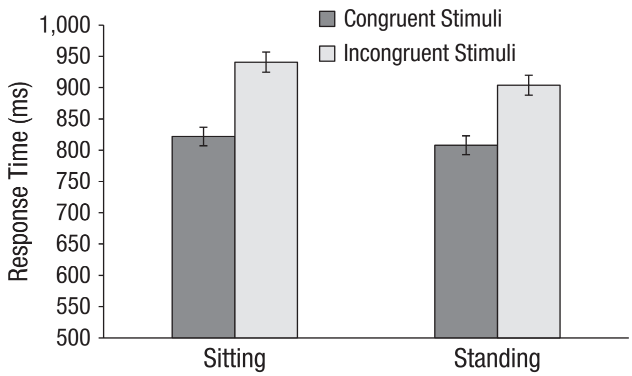

Fig. 1. Results from Experiment 3: mean response time for naming the color of congruent and incongruent stimuli, separately for the standing and sitting conditions. Error bars indicate ±1 *SEM*.

$p < .01$, $\eta_p^2 = .130$. The Stroop effects in both the sitting condition, $M = 118.9$ ms, $t(49) = 16.52$, $p < .01$, $d = 2.376$, and the standing condition, $M = 95.9$ ms, $t(49) = 14.327$, $p < .01$, $d = 2.034$, were highly reliable, but the most significant finding again was the shrinkage of the effect when participants were standing, $F(1, 49) = 8.964$, $p = .004$, $\eta_p^2 = .155$. Of the 50 participants, 35 exhibited this pattern ($p < .01$), supporting the enhancement of selectivity while standing (see the Supplemental Material available online).

Stroop effects tend to be larger when participants take longer to respond overall (Shalev & Algom, 2000). Does the smaller effect recorded for the standing condition derive from the faster overall responding in this condition? To examine this possibility, we calculated the correlation across observers between mean RT and size of the Stroop effect and found an insignificant correlation of .15. For another test, we matched the RTs across sitting and standing by scaling each observer's data to equal the overall mean across sitting and standing. We then subjected the rescaled data to an ANOVA with the same design as the one used on the original data and still found a significant interaction of posture and congruity, $F(1, 49) = 6.693$, $p = .013$, $\eta_p^2 = .120$; the Stroop effect was smaller when participants were standing. This analysis also ruled out absolute RT as the factor generating the difference in selectivity between the standing conditions and the sitting conditions.

Conclusion

The vast majority of studies in current experimental psychology are done with the participant in a sitting position (typically facing a computer monitor). In the current study, we showed that body posture affects cognition and attention. Given that the distinction between standing and sitting posture is an endogenous dichotomy, unlike such exogenous dichotomies as warm-cold or morning-evening, our findings should generalize across gender, race, or culture. After all, the present findings are contingent on human physiology. Nonetheless, our study is still based on samples of young university students, a fact that invites testing on larger populations to better pinpoint the size of the effect (see, Simons, Shoda, & Lindsay, 2017). These extensions should also advance theory, as our account is admittedly tentative. Our main purpose was to establish the empirical phenomenon. In conclusion, a new experimental psychology of standing might qualify recent results in cognitive science that are largely based on the experimental psychology of sitting.

Action Editor

D. Stephen Lindsay served as action editor for this article.

Author Contributions

All authors contributed equally in all stages of designing and running the experiment, analyzing the data, interpreting the data, and writing the manuscript, and all authors approved the final version of the manuscript for publication.

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 can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617721270

Open Practices

All data have been made publicly available via the Open Science Framework and can be accessed at https://osf.io/uwzsb/. The design and analysis plan for Experiment 3 was preregistered at the Open Science Framework and can be accessed at https://osf.io/uwzsb/. The complete Open Practices Disclosure for this article can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797617721270. This article has received badges for Open Data and Preregistration. More information about the Open Practices badges can be found at https://www.psychologicalscience.org/publications/badges.

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