Words That Move Us. The Effects of Sentences on Body Sway

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ABSTRACT

According to the *embodied cognition* perspective, cognitive systems and perceptuo-motor systems are deeply intertwined and exert a causal effect on each other. A prediction following from this idea is that cognitive activity can result in subtle changes in observable movement. In one experiment, we tested whether reading various sentences resulted in changes in postural sway. Sentences symbolized various human activities involving high, low, or no physical effort. Dutch participants stood upright on a force plate, measuring the body *center of pressure*, while reading a succession of sentences. High physical effort sentences resulted in more postural sway (greater *SD*) than low physical effort sentences. This effect only showed up in *medio-lateral* sway but not *anterio-posterior* sway. This suggests that sentence comprehension was accompanied by subtle motoric activity, likely mirroring the various activities symbolized in the sentences. We conclude that semantic processing reaches the motor periphery, leading to increased postural activity.

KEYWORDS

embodied cognition,
language processing,
postural sway,
motor control

INTRODUCTION

How do the human language system and the motor system interact? Twenty years of research have convincingly shown that these systems are deeply intertwined, and many authors embrace the view that language processing is *embodied* (e.g., Rueschemeyer, Lindemann, van Rooij, van Dam, & Bekkering, 2010). The *embodied cognition* perspective (e.g., Gallese & Lakoff, 2005) is not (yet) a grand unified theory of cognition but rather a collection of ideas and theoretical perspectives that all have in common that they regard sensory-motor experiences as the neural foundation upon which cognitive activity (e.g., language processing, mental imagery, conceptual knowledge) takes place.

At present there are (at least) four lines of evidence that demonstrate that language processing is embodied. First, various neuroimaging studies have shown that language comprehension partially activates motor structures (e.g., Binder & Desai, 2011). For example, Hauk, Johnsrude, and Pulvermüller (2004) performed a functional magnetic resonance imaging (fMRI) experiment in which participants had to read a sequence of action words, such as *kick* and *lick*. Interestingly, reading these verbs caused activation in the motor strip (motor and premotor cortex), which occurred in a somatotopic fashion, meaning that the same structures were activated when participants generated the actual movements corresponding to the verbs presented.

A second line of evidence concerns behavioral experiments, whereby researchers test whether the ease with which various motor responses are given depends on the verbal context. As a case in point, the so-called action-sentence compatibility effect (ACE) refers to the finding that certain motor responses are emitted faster than others in response to the same stimulus. For example, Glenberg and Kaschak (2002) found that, upon reading a sentence such as ”open the drawer” participants were faster in making a manual response toward the body than away from the body. According to the authors, when the direction

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DOI • 10.5709/acp-0215-9

of the action as symbolized in the sentence coincided with the direction of the motor response (i.e., they are congruent), there is no interference and responses are relatively fast, as opposed to incongruent motor responses (e.g., movements away from the body; see also Aravena et al., 2010). According to Glenberg and Kaschak, this demonstrates that "language understanding is grounded in bodily action" (p. 562).

A third line of evidence examines motor pathologies and assesses whether, and to what extent, language processing may be impaired as a result of reduced action possibilities. If so, this would clearly point to a causal role for the (intact) motor system in language processing. For example, there is some evidence that individuals with Parkinson's disease (PD) have delayed processing of action verbs (e.g., Boulenger et al., 2008; Fernandino et al., 2013), arguably because successful execution of specific actions such as running is impaired. Relatedly, the study of Cardona et al. (2014) found that ACE performance was impaired in patients with early Parkinson's disease, whereas performance was unimpaired in patients with peripheral motor pathologies. The authors concluded that the motor system and the system responsible for language comprehension are deeply intertwined, possibly mediated by loops between the cortex and basal ganglia. However, another study of Kemmerer, Miller, MacPherson, Huber, and Tranel (2013) found no evidence of a selective impairment in the speed at which action verbs are processed in individuals with PD. At present, the evidence for selective deficits in language processing (i.e., verbal items related to motor activities) in motor pathologies is mixed. This is likely due to large heterogeneity in patients' symptoms and the various ways in which subtle language deficits are measured.

A fourth line of evidence looks specifically at the role of facial muscles and to what extent linguistic material with affective content can influence activity in facial muscles. Positive and negative emotions reliably activate specific muscles, such as the *zygomaticus major* (involved in smiling) and the *corrugator supercilii* (involved in frowning), and their activity can be measured using electromyography (EMG). Various studies have found that these muscles are activated while reading sentences, such as "Mario smiles" or "Mario gets angry" (see Fino, Menegatti, Avenanti, & Rubini, 2016). Comparable findings are reported in, for example, Foroni and Semin (2013) and Thompson, Mackenzie, Leuthold, and Filik (2016). Other studies tried to assess whether facial muscle activity plays a causal role in the processing of emotional language. Havas, Glenberg, and Rinck (2007) asked their participants to rate the valence of various emotional sentences while participants held a pen in their mouth. This could only be accomplished by activating specific facial musculature which is also involved in emotional expression. The rated valence interacted with the manner in which the pen was held (pen-in-lips versus pen-in-teeth), suggesting that bodily simulation of an emotion can affect emotional language processing (see also Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009). As another example, Baumeister, Papa, and Foroni (2016) applied botulimin toxin A to the facial muscles, causing temporary paralysis of these muscles. It was found that administration of this substance interrupted processing of emotional faces and sentences, which the authors referred to as "blunting". These, and many other comparable studies, strongly suggest that the bodily state, such as muscle activity of the face, is deeply intertwined with the processing of language, such as emotional words and sentences.

In this study, we focus on a relatively neglected topic, namely the question whether processing of action sentences leads to spontaneous motor activity, especially spontaneous changes in postural control. There is evidence that cognitive activity can have a clear and direct impact on the regulation of balance. For example, motor imagery (i.e., creating a vivid mental image of a motor act) has been found to affect postural sway (Boulton & Mitra, 2013; Grangeon, Guillot, & Collet, 2011; Rodrigues et al., 2010; Stins, Schneider, Koole, & Beek, 2015). The consensus seems to be that motor imagery, especially from a first-person perspective, involves mental simulation of the motor act, leading to unintentional postural adjustments. As a case in point, a study by Boulton and Mitra (2015) revealed that imagery of arm movements under varying loads induced specific postural adjustments. The authors suggested that programming overt and covert movements (i.e., motor imagery) shared the same neural circuitry (both cortical and subcortical) and that during motor imagery, the central motor command was not completely inhibited, resulting in some degree of overt movement. As another example, it has been shown that thinking about past or future events induced changes of body posture in the anterior-posterior axis (leaning), so that "mental time travel" seemed to be embodied in postural orientation (Miles, Nind, & Macrae, 2010). On the other hand, Stins, Habets, Jongeling, and Cañal-Bruland (2016) were unable to replicate this finding, so that the robustness of this effect is still under scrutiny. With regard to postural activity and language, we know of one study that addressed the question as to whether the ACE can also be demonstrated using whole body postural movements. Zwaan, van der Stoep, Guadalupe, and Bouwmeester (2012) found that the trajectory of the body center of pressure (COP) exhibited subtle forward/backward deviations, dependent upon the directionality implied by various sentences. According to the authors, this indicates that some sort of "motor resonance" takes place automatically during language comprehension.

In our experiment, we tested whether neural activity as caused by processing verbal material "spills over" toward the motor periphery, leading to subtle muscle activation—that is, spontaneous changes in postural control. We decided to take existing neural evidence as our starting point, and we examined whether embodied language effects that have been proven to be visible in the brain also show up in postural activity. Given that quiet standing involves control of a highly unstable mechanical system (i.e., an upright body composed of multiple segments and joints), subtle changes in neural activity (in our case, related to language) can have measurable effects on the balancing response. Our study was directly motivated by an fMRI study performed by Moody and Gennari (2010). In that study, participants read sentences that varied in the level of physical effort implied by the sentences. There were three types of sentences: low physical effort (LE, e.g., "the fireman is carrying the baby"), high physical effort (HE, e.g., "the fireman is carrying the man"), and no physical effort (NE, e.g., "the fireman is happy with his job"). One of the findings was that the degree of neural activation in particular brain regions (especially prefrontal) was scaled to the effort level implied by the sentences. Moody and Gennari stated that "the sensory-motor theory of meaning argues that action words automatically activate motor plans and other action properties" (p. 783). Based on this idea, we predicted that the action representations that were activated during sentence comprehension would activate corresponding structures involved in motor control, resulting in subtle changes in observable motor output. More specifically, we tested the hypothesis that HE sentences will lead to greater postural activity than LE and NE sentences. This hypothesis was further motivated by an experiment that examined the effect of imagined effort on muscle activity. Bakker, Boschker, and Chung (1996) asked participants to repeatedly imagine lifting a light dumbbell (4.5 kg) or a heavy dumbbell (9 kg). It was found that subliminal EMG activity of the biceps muscle was higher when imagining lifting the heavy weight compared to the light weight (for a comparable study, see Guillot et al., 2007). Thus, the imagined muscle force to be exerted (which is related to effort) had a clear effect on motor output.

Stins et al. (2015) found that the type of motor activity that had to be imagined impacted body sway; there was no effect of imagining upper body activity (e.g., waving a hand) on sway, whereas there was a clear effect of lower body activity (e.g., cycling) on sway. The present experiment extends this work, and asks the novel question whether also the degree of effort embodied in action sentences affects sway. If so, this would shed further light on the complex interplay between mental simulation of actions and the control of postural stability.

METHOD

Participants

Thirty-one native Dutch speakers (10 females; 21 males; M_{age} = 23 years ± 4.4; age range = 20-45) volunteered to take part in the experiment. Participants had normal or corrected-to-normal vision and were naive as to the purpose of the study. All participants provided informed consent prior to experimentation, and the experiment was approved by the ethical committee of the Faculty of Human Movement Sciences, VU University Amsterdam.

Apparatus

To measure postural sway, participants stood on a custom-made strain gauge force plate (1 × 1 m) that sampled at a frequency of 100 Hz. The force plate consisted of eight force sensors. Four sensors measured the forces on the z (vertical) axis, two on the x axis and two on the y axis. These eight signals were automatically converted into a COP time series, separate for the medio-lateral (ML) and the anterior-posterior (AP) direction.

Sentences were made in Powerpoint and presented on an LG brand monitor (55 in.), which was positioned about 90 cm from the subject at eye height. Each sentence was displayed in a black font against a grey background, and the width of the sentences varied between 25 and 55 cm (spanning two lines). Letters were 2.5 cm high, presented in font Calibri. In order to identify the exact onset and offset of each sentence in the COP trace, we presented a small white square (not visible to the subject) in the lower left corner of the monitor, simultaneous with the presentation of each sentence. The appearance and disappearance of the white square was registered by a light sensor, which was synchronized to the COP registration system via the PC. This allowed us to uniquely identify the onset and offset of each sentence in the continuous COP trace during the off-line analysis.

Stimuli

We requested and obtained the full list of stimuli as used by Moody and Gennari (2010). We selected a convenience sample of 90 (out of 171) sentences, which we translated from English to Dutch. Each sentence represented one of three degrees of effort: either HE, LE, or NE. Note that the latter category predominantly involved purely mental activities, such as thinking or feeling. The complete list of sentences is presented in the Appendix. All sentences were presented in the present tense; most sentences (with the exception of a few LE sentences) involved transitive verbs and had a subject-verb-object structure.

Procedure

Upon entering the laboratory, subjects were asked to take off their shoes and to stand in the middle of the force plate. Participants were asked to adopt a relaxed upright body posture and to keep their arms alongside the body. During standing, subjects saw and read (in silence) each of the 90 stimulus sentences, which were presented in a complete random order. In order to keep attention high to the meaning of the sentences, the reading task was embedded in a memorization task. This was done as follows: Sentences were always presented in triplets and after each third sentence, a fourth (control) sentence was presented. The task of the subjects was to read each of the test sentences and then to determine whether the control sentence was identical to one of the three previous sentences (which was the case in 50% of the cases). This was indicated by simply saying "yes" or "no" after each control sentence. Experimenters kept track of whether the answer was correct or not. Notice that this was not a very difficult task, as the control sentences were sufficiently different from the test sentences. The control sentences requiring a "no" answer were sentences adopted from the same stimulus set as described above, but they never appeared in the triplets. Examples of control sentences were "de muzikant geeft de cello aan" ("the musician is handing over the cello"), and "de mijnwerker trekt aan het touw" ("the miner is pulling the rope"). We presented the control sentences in a font that was sufficiently different from the sentences in the triplets, namely Calibri, red color, italics, 2.5 cm high. Simply reading and attending to the triplets of sentences was in general sufficient to provide the correct answer. Overall, the proportion of erroneous trials was low (see Results section below) and such data were discarded.

The timing of the stimulus events was as follows: Each triplet consisted of the following events: fixation cross (5 s), first sentence (3 s), fixation cross (5 s), second sentence (3 s), fixation cross (5 s), third sentence (3 s), fixation cross (5 s), control sentence. The control sentence remained on the screen as long as was necessary for the participant to answer "yes" or "no" after which the experimenter manually started the next triplet by pressing a key on the computer keyboard.

Analysis

Figure 1 shows an example raw COP trace section. We first used a 5-point moving average (function *smooth* in Matlab) to filter the data. We then identified the sections in the COP trace where a sentence was presented (see Figure 1). As our measure of postural (in)stability, we calculated the within-trial *SD* of the COP excursions, separately for the AP and ML direction of each 3-s sentence. Low values suggest that the subject was standing motionless, whereas high values are suggestive of relatively much postural activity (see Stins et al., 2015). Note that the COP is a complex output signal, signifying a pattern of muscle activity that is employed to stabilize the mechanically unstable upright human body. The relationship between muscle activity and COP excursions is not a simple one-to-one relationship. For example, one could coactivate the *soleus* and *tibialis* muscles (an agonist–antagonist pair spanning the ankle joint) and still have very little net bodily movement. Despite this, large COP excursions may signify posturo-muscular activity, and the *SD* of the COP is the most straightforward index of sway activity. More complex measures, for example, examining frequency contents, are also often adopted but they require longer consecutive time series.

Design and Statistical Analyses

The experiment consisted of a one-way repeated-measures design with the effects of the three levels of the factor language being measured in the AP and ML body sway axes in a within-subject fashion. Thus, the *SD*s associated to body sway in the AP and ML axes were the dependent measures, and the independent measures were the three levels of the factor language—that is, HE, LE, and NE sentences.

The arithmetic mean *SD* in each language condition and body sway axis was estimated for each participant, and the normality of the *SD* distribution for each language condition in the ML and AP axes was examined graphically via Q-Q plots (see Loy, Follett, & Hofmann, 2016) and statistically via the Shapiro-Wilk normality test (see Marmolejo-Ramos & González-Burgos, 2013). The Shapiro-Wilk test indicated that some vectors of data did not distribute normally in both AP and ML data; specifically, for the AP axis: $W_{HE} = 0.95$, $p = .2805$, $W_{LE} = 0.93$, $p = .051$, and $W_{NE} = 0.85$, $p < .001$; and for the ML axis: $W_{HE} = 0.89$, $p = .004$, $W_{LE} = 0.88$, $p = .003$, and $W_{NE} = 0.87$, $p = .001$. Thus, ML and AP data were logarithmically (base 10) transformed (see Marmolejo-Ramos, Cousineau, Benites, & Maehara, 2015; Vélez, Correa, & Marmolejo-Ramos, 2015). A one-way repeated-measures analysis of variance (ANOVA) was performed on the transformed AP and ML data separately, and results were graphically displayed via shifting boxplots (Marmolejo-Ramos & Tian, 2010). The *p* values of pairwise two-tailed *t*-test comparisons were corrected via the false discovery rate method, p_{FDR} (Benjamini & Hochberg, 1995). Effect size of the ANOVA is reported as partial eta-squared (η_p^2).

Finally, we decided to use Bayesian statistics to assess the relative evidence for the null hypothesis vis-à-vis the alternative hypothesis, given the observed data. The Bayesian approach is rapidly gaining popularity and can be seen as a complement to traditional null hypothesis significance testing. We will not dwell here on the conceptual differences between the approaches but simply report the outcomes of the Bayesian pair-wise comparisons[1]. For accessible treatments of Bayesian statistics, we refer the reader to Dienes (2014). We performed the analyses using JASP (version 0.7.5.5; JASP Team), with the default Cauchy prior width of .707 (see Stins et al., 2016). Results are reported in Bayes factors (BF), which quantify the predictive success of the null hypothesis, relative to the alternative hypothesis. A BF smaller than 1/3 indicates substantial evidence for the null, whereas a BF greater than 3 indicates substantial evidence for the alternative. Intermediate values are considered inconclusive for either hypothesis.

RESULTS

Prior to the analysis, we excluded a number of trials. First, if the participant was not able to correctly identify the test sentence, we reasoned that the triplet of sentences was possibly not attended to, so we decided to discard the complete set of three trials. This happened on 23 occasions, thus, we removed 69 trials in total. Second, visual inspection

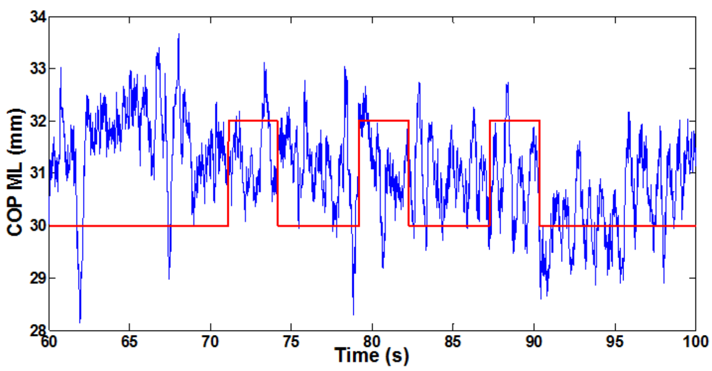

FIGURE 1.

Example raw center of pressure (COP) trace (blue) in the medio-lateral (ML) direction. The red line corresponds to onset / offset of the sentence.

revealed excessive postural movement on some trials for reasons unknown (perhaps due to a weight shift or involuntary bodily movement). Based on visual inspection, we decided to treat trials wherein the *SD* in the AP direction was larger than 1 cm and trials wherein the *SD* in the ML direction was larger than 4 mm as outliers, resulting in removal of 3 additional trials. Thus, 72 out of 2790 trials (2.6%) were not entered into the analysis.

The one-way repeated-measures ANOVA indicated the log-*SD*s associated to the three language conditions differed significantly on the ML axis, $F(2, 60) = 4.74$, $p = .012$, $\eta_p^2 = .27$, but not on the AP axis, $F(2, 60) = 0.20$, $p = .813$, $\eta_p^2 = .01$.

Pairwise comparisons between the log-*SD*s of the language conditions in the ML axis showed that HE sentences were associated with higher log-*SD*s ($M = -.15 \pm .11$) than LE sentences ($M = -.17 \pm .10$), and NE sentences ($M = -.15 \pm .10$) had higher log-*SD*s than LE sentences; $p_{FDR} = .02$ in both cases. Figure 2 shows shifting boxplots representing key characteristics of the sample distribution for the three conditions, in both sway axes.

The results of the Bayesian analysis are presented in Table 1, where we compared all three contrasts, separately for the ML and the AP axes. Three important points emerge from this analysis. First, all contrasts for the AP axis were smaller than 1/3, indicating substantial evidence for the hypothesis that postural performance on either effort level was identical. Second, for the ML axis, there was substantial evidence for a difference between the HE and LE conditions, and between the NE and LE conditions (BFs > 3), corroborating our finding of reduced sway in the LE condition relative to the alternate conditions. In contrast, there was substantial evidence for no difference between the HE and NE conditions. In other words, the BFs pointed in the same direction as the *p* values obtained in the significance test. A third observation is that none of the BFs was inconclusive—that is, between 1/3 and 3. This means that the effects were unambiguous[2].

TABLE 1.
Results of the Bayesian Pairwise Comparisons, for All Three Effort Combinations

Contrast	AP-axis	ML-axis
HE-LE	0.222	5.541
HE-NE	0.221	0.224
LE-NE	0.194	3.502

Note. Bayes factors (BFs) are presented for log-*SD*s data. BFs greater than 3 represent substantial evidence for the alternative hypothesis, and BFs smaller than 1/3 represent substantial evidence for the null. ML = medio-lateral direction; AP = the anterior-posterior direction; HE = sentences implying high body effort; LE = sentences implying low body effort; NE = sentences implying no body effort.

DISCUSSION

The aim of this study was to test whether comprehending various action sentences would result in changes in spontaneous postural adjustments, arguably mediated by shared neural circuits. If so, this would provide evidence for the notion that semantic processing is embodied. As a test of this hypothesis, we presented Dutch native speakers with a sequence of sentences that varied in the level of physical effort implied in the sentences.

Our main prediction was that HE sentences resulted in a greater amount of postural sway compared to LE sentences and, indeed, we found convincing evidence for this hypothesis. Statistical analyses based on significance testing and on Bayesian comparisons of means clearly confirmed this idea. It thus seems to be the case that reading and memorizing sentences that refer to high physical effort triggered the corresponding action representations (e.g., carrying a heavy object). These representations, in turn, activated the motor programs (at least, to some extent), resulting in postural movements. A similar conclusion was drawn by Stins et al. (2015), who found context-dependent effects of motor imagery on postural sway, which was taken to be in line with the theoretical notion that (some) purely mental activity is grounded in sensory-motor experiences. Our results are also consist-

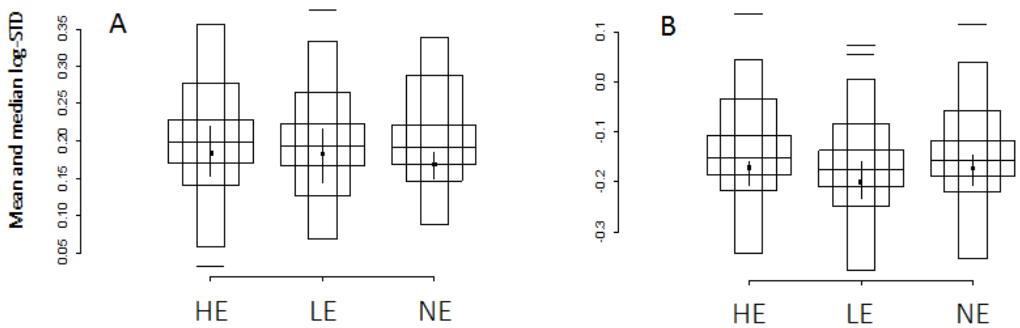

FIGURE 2.
Shifting boxplots representing the distribution of mean values of postural sway in the anterior-posterior (AP, side A) and medio-lateral (ML, side B) directions for the three conditions. Observations lying ± 2 *SD* beyond the mean are represented by dashes, observations between −2 and +2 *SD* are represented by the longest and thinnest box. Observations that fall between the mean of the first half of the data and the mean of the second half of the data are represented by the intermediate box. The middle thickest and longest horizontal line represents the mean of the data and its 95% bootstrap bias-corrected and accelerated CIs (95% CIBCa) are represented by the outermost box. The median and its 95% CIBCa are represented by a solid small square and whiskers around it (see Marmolejo-Ramos & Tian, 2010, for details). HE = sentences implying high bodily effort; LE = sentences implying low bodily effort; NE = sentences implying no bodily effort.

ent with the study of Bakker et al. (1996), who found that imagined muscle force was related to subliminal EMG activity. More generally, our results are in line with other embodied cognition accounts. For example, there is convincing evidence that the processing of emotional language (either words or whole sentences) activates the same neural circuitry as the emotions themselves, and that peripheral somatic states (e.g., facial muscles) can influence the simulation of actions, and the subsequent processing of language (e.g., Havas & Matheson, 2013; see also the Introduction section).

There are two findings in our data that warrant further explanation. First, why was the effect found only in the ML axis and not the AP axis? Note that Stins et al. (2015) also found postural effects in the ML but not the AP axis. In both that study and the current one, many action representations arguably involved sideways (bilateral) leg movements, for example, dragging or carrying a heavy object. It could be the case that these actions resulted in sideways postural oscillations but not front-to-back oscillations.

Second, why did the NE condition behave the way it did? That is, why did the NE condition result in more ML sway than the LE condition? It could be that the NE condition was somewhat more complex than the other two conditions. The NE condition involved more abstract activities (e.g., worrying, observing, etc.), which could be harder to imagine than the concrete physical activities symbolized by the LE and HE sentences. Moody and Gennari (2010) had obtained imageability ratings on a scale from 1 to 7 for each sentence, and they found an average imageability rating of 3.1 for the NE sentences, which was significantly lower than the imageability ratings of the LE and HE sentences (5.1 and 5.2, respectively). In addition, there is evidence from the neuroimaging literature (e.g., Sakreida et al., 2013) that abstract words (nouns and verbs, such as *to marvel*) are processed in different cortical networks than concrete linguistic items (e.g., *to draw*). Thus, the NE sentences could require more attentional processing, resulting in a dual-task effect, affecting postural sway (e.g., Pellecchia, 2003). Perhaps future studies on the postural embodiment of language should adopt more fine-grained effort levels in the sentences (e.g., low, middle, high), to test whether postural sway scales with effort. In addition, one could further investigate the role of experienced effort on cognition. Proffitt (2006) claimed that anticipated physical effort had a profound influence on perception and cognition (but see Firestone & Scholl, 2016), and it is unknown to what extent such individual variations have an impact on body sway.

This study is not the first to examine the effect of language on postural balance. However, existing studies have typically employed language in a dual-task setting to probe the attentional requirements of postural control when faced with a secondary cognitive task. For example, Kerr, Condon, and McDonald (1985) found that posture was affected by processing spatial visual stimuli but not by verbal (nonspatial) stimuli. The current study was not designed to probe the limited attention system, but to test whether semantic processing was accompanied by unintentional postural adjustments. We indeed found evidence for this prediction, and our findings are in line with an embodiment account.

On a final note, note that this study cannot be used to demonstrate whether or not the motor system is causally involved in language. Pulvermüller and Fadiga (2010) argued that the motor system plays an active role in language comprehension. In a similar vein, Barsalou (2008) argued that perceptual and motor states lie at the heart of much, if not all, cognitive activity, including language. However, according to others (e.g., Mahon & Caramazza, 2008), observed motor activity might simply be an epiphenomenon—that is, a side effect of language processing. Our aim in this paper is not to provide evidence for or against either perspective. However, a paradigm whereby certain postural movements are imposed, possibly affecting the timing or nature of language processing, could shed more light on this issue.

FOOTNOTES

[1] This is sometimes also called a Bayesian *t* test, but, strictly speaking, this is incorrect, because no *t* values or *p* values are calculated. We are dealing here with a Bayesian comparison of means.

[2] All the analyses reported here gave the same pattern of results when applied to the untransformed data.

AUTHOR NOTE

We thank C. L. Moody and S. P. Gennari, who kindly agreed to share their raw stimulus material with us. We also thank Daniëlle Bouman for her kind assistance in setting up the experiment and analysing the data. Finally, we thank the reviewers for their helpful suggestions and many insightful comments.

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RECEIVED 26.10.2016 | ACCEPTED 18.04.2017

APPENDIX A

The complete list of sentences used in this study.

Item	Dutch sentence	English sentence	Effort level
1	de tuinman bekijkt de kruiwagen vol met bladeren	the gardener is observing the wheelbarrow full of leaves	No
2	de tuinman duwt de kruiwagen vol met stenen	the gardener is pushing the wheelbarrow full of stones	High
3	de tuinman duwt de kruiwagen vol met bladeren	the gardener is pushing the wheelbarrow full of leaves	Low
4	de bouwvakker heeft de lege emmer van de leerling nodig	the builder needs the empty bucket from the apprentice	No
5	de bouwvakker geeft de volle emmer aan de leerling	the builder is giving the full bucket to the apprentice	High
6	de bouwvakker geeft de lege emmer aan de leerling	the builder is giving the empty bucket to the apprentice	Low
7	de jager herinnert zich het dode hert	the hunter remembers the dead deer	No
8	de jager tilt het dode hert op	the hunter is picking up the dead deer	High
9	de jager tilt het dode konijn op	The hunter is picking up the dead rabbit	Low
10	de kok heeft een hekel aan de sausjespan	the chef hates the saucepan	No
11	de kok tilt de koelkast op	the chef is lifting the fridge	High
12	de kok tilt de sausjespan op	the chef is lifting the saucepan	Low
13	de boer denkt aan de met tas boodschappen in de truck	the farmer is thinking about the bag of groceries in the truck	No
14	de boer zet de tas met aardappels in de truck	the farmer is putting the bag of potatoes on the truck	High
15	de boer zet de tas met boodschappen in de truck	the farmer is putting the bag of groceries on the truck	Low
16	de leraar heeft een hekel aan examens	the teacher detests exams	No
17	de leraar stapelt de stoelen op	the teacher is stacking the chairs	High
18	de leraar stapelt de examens op	the teacher is stacking the exams	Low
19	de bezorger is de piano vergeten	the delivery man has forgotten the piano	No
20	de bezorger duwt de piano	the delivery man is pushing the piano	High
21	de bezorger duwt de stoel	the delivery man is pushing the chair	Low
22	de arbeider merkt het zand in de emmer op	the worker noticed the sand in the bucket	No
23	de arbeider giet het zand in de emmer	the worker is pouring sand into the bucket	High
24	de arbeider giet de cornflakes in de kom	the worker is pouring cereal into the bowl	Low
25	de bokser houdt van zijn witte sporttas	the boxer loves his white gym bag	No
26	de bokser draagt zijn grote bokszak	the boxer is carrying his large punch bag	High
27	de bokser draagt zijn witte sporttas	the boxer is carrying his white gym bag	Low
28	de houthakker negeert de boomstam	the woodcutter is ignoring the log	No
29	de houthakker draagt de boomstam	the woodcutter is carrying the log	High
30	de houthakker draagt de zaag	the woodcutter is carrying the saw	Low
31	de visser slaapt in de boot	the fisherman is sleeping in the boat	No
32	de visser sleept de boot	the fisherman is dragging the boat	High
33	de visser sleept de vissen	the fisherman is dragging the fish	Low
34	de houthakker kijkt naar de boomstam op de truck	the lumberjack is looking at the log on the truck	No
35	de houthakker legt de grote boomstam op de truck	the lumberjack is putting the large log on the truck	High
36	de houthakker legt de kleine zaag op de truck	the lumberjack is putting the small saw on the truck	Low
37	de atleet merkt de frisbee op	the athlete noticed the Frisbee	No
38	de atleet gooit de speer	the athlete is throwing the javelin	High
39	de atleet gooit de frisbee	the athlete is throwing the Frisbee	Low
40	de winkelier is blij met de kleine snoepjes	the shopkeeper is satisfied with the small sweets	No
41	de winkelier stapelt de grote blikken op	the shopkeeper is stacking big tins	High
42	de winkelier stapelt de kleine snoepjes op	the shopkeeper is stacking small sweets	Low
43	de zakenman is blij met zijn grote paraplu	the businessman is pleased with the big umbrella	No

44	de zakenman draagt een grote koffer	the businessman is carrying the big suitcase	High
45	de zakenman draag de grote paraplu	the businessman is carrying the big umbrella	Low
46	de vrouw kijkt naar de volle kan	the lady is peering at the full pitcher	No
47	de vrouw pakt de volle kan	the lady is fetching the full pitcher	High
48	de vrouw pakt het kleine souvenir	the lady is fetching the small souvenir	Low
49	de arbeider heeft een houten emmer nodig	the workman needs a wooden bucket	No
50	de arbeider pakt een biervat op	the workman is picking up a beer barrel	High
51	de arbeider pakt een lege emmer op	the workman is picking up an empty bucket	Low
52	de boer is bezorgd over het paard	the farmer is worried about the horse	No
53	de boer duwt tegen het paard	the farmer is pushing the horse	High
54	de boer duwt tegen de deur	the farmer is pushing the door	Low
55	de man heeft een hekel de truck	the man hates the truck	No
56	de man duwt tegen de truck	the man is pushing the truck	High
57	de man duwt tegen het bureau	the man is pushing the desk	Low
58	de postbode is de uitpuilende pakketten vergeten	the postman has forgotten the bulging packages	No
59	de postbode stapelt de uitpuilende pakketten op	the postman is piling the bulging packages	High
60	de postbode stapelt de dunne enveloppen op	the postman is piling the flimsy envelopes	Low
61	de brandweerman is blij met zijn baan	the fireman is happy with his job	No
62	de brandweerman draagt de man	the fireman is carrying the man	High
63	de brandweerman draagt de baby	the fireman is carrying the baby	Low
64	de verpleegster bewondert de patiënt	the nurse admires the patient	No
65	de verpleegster tilt de patiënt op	the nurse is lifting the patient	High
66	de verpleegster tilt de plant op	the nurse is lifting the plant	Low
67	de tuinman is blij met de bank	the gardener is happy with the bench	No
68	de tuinman trekt aan de bank	the gardener is pulling the bench	High
69	de tuinman trekt aan het hek	the gardener is pulling the gate	Low
70	de kunstenaar is nieuwsgierig naar het grote schilderij	the artist is curious about the big drawing	No
71	de kunstenaar haalt het grote beeldhouwwerk op	the artist is fetching the big sculpture	High
72	de kunstenaar haalt het grote schilderij op	the artist is fetching the big drawing	Low
73	de tuinman is blij met de boom	the gardener is pleased with the tree	No
74	de tuinman sleept de boom	the gardener is dragging the tree	High
75	de tuinman sleept de takken	the gardener is dragging the branches	Low
76	de motorrijder merkt zijn helm op	the rider noticed his helmet	No
77	de motorrijder tilt de motor op	the rider is lifting the motorcycle	High
78	de motorrijder tilt de helm op	the rider is lifting the helmet	Low
79	de bezorger is nieuwsgierig naar de lege krat	the delivery man is curious about the empty crate	No
80	de bezorger pakt de volle krat op	the delivery man is fetching the loaded crate	High
81	de bezorger pakt de lege krat op	the delivery man is fetching the empty crate	Low
82	de bergbeklimmer slaapt bij zijn tas	the mountaineer is sleeping by his pack	No
83	de bergbeklimmer sleept zijn tas	the mountaineer is dragging his pack	High
84	de bergbeklimmer sleept zijn stok	the mountaineer is dragging his stick	Low
85	de elektriciën heeft een ladder nodig	the electrician needs his ladder	No
86	de elektriciën verplaatst de ladder	the electrician is moving his ladder	High
87	de elektriciën verplaatst de spiegel	the electrician is moving the mirror	Low
88	de verpleegster observeert het grote bed	the nurse is observing the large bed	No
89	de verpleegster sleept het grote bed	the nurse is dragging the large bed	High
90	de verpleegster sleept de kleine stoel	the nurse is dragging the small chair	Low