In Tune with IN-POCO? A New Device for Analyzing and Training the Interplay of Body Posture and Charismatic Speech Prosody

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Abstract: Our paper introduces a new technology for posture research and training: the INteractive POsture COrrector, IN-POCO. The device warns its users about unfavorable postures when speaking (e.g., sitting in video conferences) and is thus suitable as an aid for rhetoric trainers. In addition, IN-POCO can also collect time-aligned posture and speech signals for researching prosody-posture relationships in the speech sciences. We outline the motivation for the development of IN-POCO and describe the key technical specifications and operational characteristics. The paper concludes with a pilot experiment in which we provide initial evidence that, for a communicative (public) speaking task, posture does indeed affect speech prosody in gender-specific ways – in line with claims of rhetoric trainers and guidebooks, and such that an unfavorable (e.g,, humped) posture can be assumed to reduce the speaker's vocal charisma.

1 Introduction

Posture is a topic of growing relevance not only due to the increasing prevalence of working, learning, and playing (gaming) in a seated position in front of a screen, which makes many individuals adopt a posture characterized by a hunched back or forward-leaning neck [9]. Besides obvious orthopedic concerns, rhetorical guidebooks suggest that such a posture may also exert a negative influence on a speaker's prosody-based vocal charisma, defined here as the ability to attract attention and persuade others. For instance, [1:212] summarizes the benefit for speakers by asserting that “a straight posture helped them to throw their voice to the room.” Sapate and Bawge [2:42] further elaborate that a “relaxed, balanced, and straight posture enhances the impressiveness of voices,” in accord with Kühl [3], who underscores multiple times in her book that a straight posture and a powerful, persuasive speech are closely intertwined.

The speech sciences do not provide empirical support for such claims of public-speaking trainers. However, the special communication situation of public speaking has never been in focus so far. When prosody and posture have been jointly examined, the focus was either on research subjects other than vocal charisma, such as Lombard speech and vocal effort [4], or on posture variables related to hand or arm gestures rather than to the body’s shape and position itself [5]; or, investigations delved into the multimodal aspects of cognitive processing of communication signals, such as the reciprocal influence of (mis)matching posture and prosody signals on the perception of emotions [6].

Apart from the fact that the topic of body posture and its interplay with speech prosody are strongly under-researched, indirect evidence from the field of forensics challenges the aforementioned claims of rhetorical guidebooks. Flory [7] and Nolan and Flory [8] conducted research within a forensic context to identify the phonetic and prosodic characteristics associated with different postures. Their findings suggest that speakers were able to compensate for the biomechanical constraints of various postures within seconds. Consequently, the measured acoustic-phonetic differences between different postures were marginal, and listeners could not differentiate beyond chance the audio-only stimuli corresponding to different postures, even those that were as different as ‘sitting’ vs. ‘standing’.

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So, does it make sense to give learners of public speaking feedback on their body posture? The visual impression alone suggests a positive answer, because attractiveness and an open, straight posture can have a positive effect on the speaker's perceived visual charisma, see the summary in [10]. Even more important could be that an upright posture (sometimes referred to as a type of "power pose" in relation to a more unfavorable, humped posture, [11]) also influences the mindset of the speaker himself. Speakers feel stronger, more self-confident and better able to face the challenges ahead when adopting a straight, upright posture, see the puzzle example in [12]. Since prosody is very sensitive to changes in a speaker's mental state [13], it would be plausible to assume that this posture-related change in mindset, unlike the biomechanical consequences of a posture change itself, manifests itself in prosody. If that could be shown, then posture feedback in public speaking would also make sense from a vocal-performance perspective – over and above the obvious visual-performance perspective.

Against this backdrop, we introduce here a new hardware device for the measurement, evaluation, and training of body posture during (public) speaking: IN-POCO, the INteractive POsture COrrector, see Figure 1 and the provided illustration video[1].

Figure 1 – Illustration of the IN-POCO device and its application. Photos : taken by authors.

2 What is IN-POCO? A resume of key features

The IN-POCO system is designed to be adaptable to various body shapes and sizes. The adaptation is achieved via a three-step calibration while the user wears it. IN-POCO provides real-time feedback to public speakers and/or records and stores data for research purposes. Incorporating a start/stop button, the system emits a sound signal when the 'start' button is pressed and a feedback or data-collection session starts. The sound signal moreover indicates the onset of a time-synchronous recording of posture and acoustic speech signal.

The key components of IN-POCO, the stretch sensors, consist of an electroactive polymer (EAP) with an almost linear stretching/mm-to-voltage response. They are highly responsive, offering a precision of < 1 mm in posture detection. Equally importantly, the sensors' inherent elasticity is so low that the wearer's natural body movements are not significantly influenced by the sensors' restoring forces. For example, even with maximum stretching (8 cm), the restoring force is only 300 grams, while, with normal body movements and postures, it is significantly less than 50 grams.

IN-POCO is also designed for a handy, largely self-explanatory operation. It features a compact, sturdy and at the same time small and lightweight casing for the electronics to which also a headset microphone can be connected. The user interface includes an easily readable one-inch 128x64 OLED display and a text menu for navigation to configure settings and make adjustments. The system has a battery life of approximately 9-11 hours, utilizing a 2.6 Ah li-ion

[1] https://www.youtube.com/watch?v=Ck8LuvRY_4k

battery. The device is equipped with a USB-A interface in order to recharge the battery (5V, maximum 1 A).

To ensure hygiene, both casing and harness are alcohol-wipeable for disinfection between use by different people, such as in a public-speaking coaching scenario. Recorded data is stored on a removable SD card in both CSV and WAV formats, allowing an easy export and analysis of the data by either coaches or researchers. Finally, designed to be inconspicuous, the system can be worn underneath the clothes during a live public speech, in that way providing discreet vibration feedback to its wearer (i.e. alerting him/her to speaking in an unfavorable posture).

3 Sensor placement and harness design

The sensor placement along the harness of the IN-POCO system was inspired by the Upper Crossed Syndrome (UCS), a common poor posture that occurs in our modern society primarily due to frequent sitting and the growing use of digital media [9]. In particular, long hours of sitting at a computer at work or for video games, watching TV, or using a smartphone can contribute to UCS. UCS is considered one of the most common bad postures of our time. Such a UCS-like posture is also assumed when speaking in public (standing) and, especially, when sitting in front of the screen during video calls [1]. The obvious postural characteristics of UCS are protracted shoulders, a forward head in front of the body, and an apparent curve in the neck and upper back [9].

The UCS symptoms mainly manifest themselves along the Trapezius muscle on the back, and, accordingly, this is where the IN-POCO sensors are placed, see the yellow shapes in Figure 2. IN-POCO includes three stretch sensors. They are oriented vertically along the wearer's back. Two extend from the left and right shoulder blades up to the tip of the respective shoulder (acromion), thus covering the mid and upper parts on both sides of the Trapezius. A third sensor extends along the spine, which represents the middle center of the Trapezius muscle.

The harness design process involved iterative sketches aimed at optimizing ease of donning and doffing – as if it was a T-shirt. It is shown in Figure 2 with different colors that correspond to distinct materials or components. The harness is crafted from a combination of stretchable Garter material (indicated in orange, Fig. 2) and non-stretch Nylon straps (indicated in red, Fig. 2). Garter material, worn directly against the skin, provides comfort and conforms to the user's body structure with minimal resistance. Non-stretch Nylon serves to impart structural integrity, while facilitating unhindered user movement and directing any stretching forces to the sensors. The two materials are joined at specific points highlighted in blue (Fig. 2). The harness, when worn, maintains its shape without pinching; and to enable controlled extension, a clamping mechanism (depicted in green at the tip of Nylon straps, Fig. 2) is incorporated. This allows users to secure the harness to belts or pants, preventing its shifting during use.

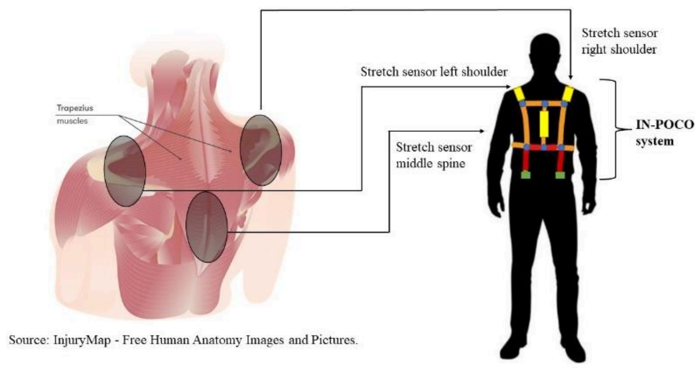

Figure 2 – Illustration of how the IN-POCO is composed (the human silhouette shows the wearer's back) and of how the three stretch sensors are placed in relation to the Trapezius muscle (anatomical figure used here with changes under CC-BY-SA-4.0 license from Wikimedia Commons).

4 Calibration and operation

The operation of the IN-POCO device is controlled through three buttons on the electronics casing. In addition, located on the side of the casing, are also the sliding power switch, the USB-A charging port, and the Micro-SD card slot. Activating the device with the sliding power switch illuminates the OLED display which presents the main menu to the user.

When utilized as an interactive feedback device, an initial crucial step is to calibrate the sensor measurements and feedback thresholds according to the user's size and body shape. To do this, the user navigates the cursor to the 'Reset Pos. Threshold' option, using the directional 'up/down' buttons. The option defines the start of the assessed posture range. The start posture typically represents the optimal, straight posture, see Figure 3. Upon assuming the optimal posture, the user presses the 'enter' button with a finger from the left hand, avoiding shoulder bending. This sets the optimal posture values for all three sensors.

Next, the user defines the end of the assessed posture range. Navigating to the 'Reset Leaned Thresh' option, the user assumes the worst posture, and then again presses the 'enter' button to define and fix this second landmark, see Figure 3. Upon this button press, the sensors' threshold values are automatically calculated and, by default, the feedback threshold level is set to the lowest level, i.e. 1 on a scale from 1-10. Now, the device is basically ready for use.

However, if desired, users can customize the sensors' feedback sensitivity in the 'Adjust Thresholds' menu separately for each of the three sensors, i.e. left shoulder, right shoulder, spine/ lower back. A threshold level of 10 switches off any feedback vibration of the respective sensor, whereas a threshold level of 1 is most sensitive and causes the respective sensor to vibrate already for any minor deviation from the initially defined (optimal posture) threshold. In general, the higher the value, the later the feedback vibration sets in and warns the wearer of a poor posture within the defined range between the first (optimal) and second (worst) posture.

When the user is satisfied with all three vibration-feedback thresholds, s/he can start the recording/feedback session. To do that, the user must return to the main menu via the 'Go Back' option and press 'Start Recording'. Stopping the recording is done by simply pressing the 'enter' button. Note that a new recording can be made without extracting the Micro-SD card and reading out and/or removing previous data. With every further recording/feedback session, the new data is, in a clearly marked way, attached at the end of the previously recorded data file.

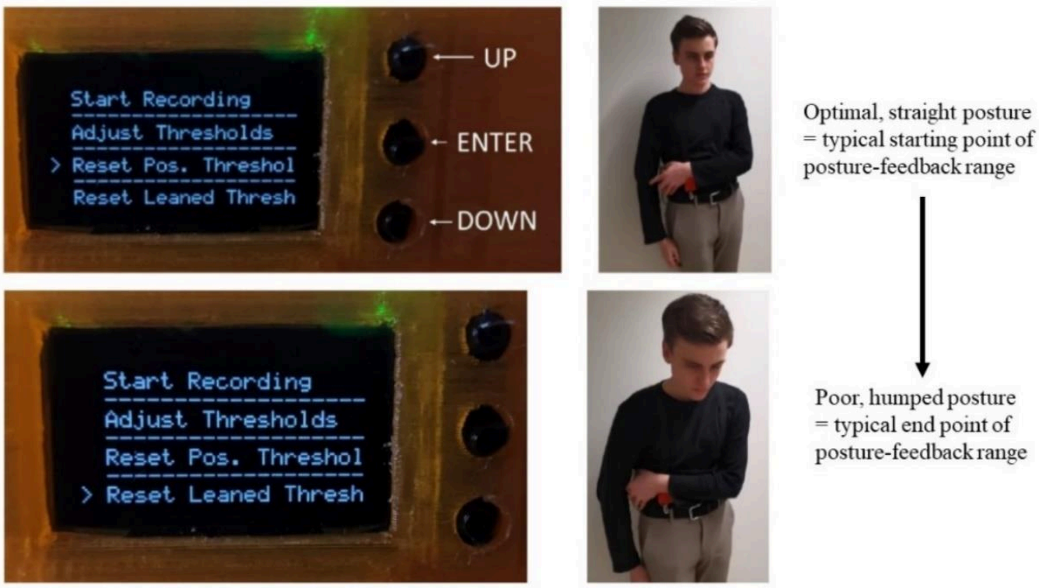

Figure 3 – Definition of starting point and endpoint of assessed feedback range. The two posture landmarks typically correspond to a straight and humped posture, respectively. Photo shows 1st author.

5 The posture-prosody link: A pilot study

As was explained above, forensic phonetic studies by [7] and [8] suggest that speakers can compensate for the physiological and biomechanical effects of their posture on speech acoustics within seconds and that, thus, any acoustic differences caused by posture changes, if measurable at all, are at best marginal. Accordingly, also listeners could not reliably discriminate or even identify postures in audio stimuli.

However, it would be premature to simply assume that these findings can also be generalized to public speaking. The studies [7] and [8] are based on artificial language material – i.e. sustained vowels and isolated sentences – which were elicited without a communicative context. On the one hand, this was useful as it allowed focusing on the physiological and biomechanical effects of posture changes. But, on the other hand, this non-communicative approach is not able to uncover and determine any mental and mindset-related effects of posture on phonetics, particularly on prosody or vocal performance. To test this mental or mindset-related posture-prosody link, we conducted an initial pilot experiment, which is presented below.

5.1 Speakers

Eight fluent (but non-native) speakers of English participated in the study, 4 males and 4 females. They were between 25-45 years old and staff members of the University of Southern Denmark (SDU), hence had a similar high level of education.

5.2 Speech Material

Our speakers engaged in oral reading of 'The Rainbow Passage,' a phonetically balanced English text. Comprising a total of 1,096 phonemes, including 108 content words, this passage is widely adopted in the speech sciences for its standardized nature, enabling comparisons across various studies. Our selection of this text is not only rooted in its utility for benchmarking speech data but also in its capacity to evoke fluent, emotionally nuanced speech. In comparison to alternative texts, 'The Rainbow Passage' incorporates a higher percentage of high-arousal words (17.5 %) and a lower percentage of less familiar words (5.5 %) [14].

5.3 Procedure

From our public-speaking training we know that poor postures with a hunched back and/or a forward-leaning neck – or with the entire symptom range that belongs to the UCS [9] – occur with particularly high degrees of severity and consistence when sitting. Therefore, in this first pilot study we collected the speech material of our speakers while sitting.

The study was conducted in individual sessions in a comfortable, sound-treated room at the University of Southern Denmark. At the beginning of a session, speakers received the 'Rainbow Passage' on a piece of paper and were given the opportunity to familiarize themselves with the text – until they signaled that they were ready for the speech recording. In response to this notification, a headset microphone (Sennheiser HSP2 EW3) was placed on the speaker's head and connected via a preamplifier (Behringer Uphoria UMC292) to a laptop, which recorded the speech signal at 48 kHz, 16-bit quality.

The speakers were instructed to produce the 'Rainbow Passage' two times. More specifically, it was pointed out to them that the text should not be produced as a self-directed speech, but in an audience-oriented style that would be interesting and stimulating for listeners. In other words, the text was supposed to be "performed" rather than merely read. In addition, speakers were told to read the text twice: once with a straight, upright posture (preferably with their back against the back of the chair for reference) and once with a severely humped posture (the slumped kind of sitting on the chair that the speakers all knew well from long video meetings).

Finally, it was told to the speakers that filled pauses would be no problem and no reason to interrupt the speech, but that they were basically allowed to restart sentences that were misread.

The two posture conditions were balanced across both the speaker gender and the speaker sample as a whole. That is, half of the speakers in each gender group started with the humped posture and the other half with the straight posture.

At the end of the session there was a de-briefing about the objectives and analyzed parameters of the study. An entire session, including de-briefing, lasted about 10 minutes.

5.4 Data analysis

The analysis of the data was conducted using an own script that was inspired by the established Prosody Pro script by Xu [15]. That is, similar parameters were measured as with Prosody Pro, but within a Python framework and based on an automatic pre-segmentation of the data into inter-pausal units (IPUs). This pre-segmentation used the same default settings as the 'Sounding' vs. 'Silence' segmentation in PRAAT. In addition, our own Python script also included some more reliable f0 measures (such as f0 minima and maxima represented by the 10^{th} and 90^{th} quartiles in order to largely exclude octave errors) as well as intensity (RMS) variability, and variability (standard deviation) measures of f0 and several spectral tilt estimates like H1-H2, H1-A1 H1-A3 (all pitch-corrected), and the Hammarberg Index. Furthermore, silent pauses (> 100 ms) and pause durations are determined by our Python script.

5.5 Results

Because of the relatively small sample size, we have refrained from running a proper inferential statistics on our data. Such a statistics will come once the sample size includes a larger number of speakers. Thus, the results summary below is preliminary and descriptive in nature. However, as a way of selecting results that will likely come out significant in future statistics, we report only those posture-related prosodic differences below that were consistent across all male or female speakers. So, if a certain prosodic parameter is reported to be higher or lower in combination with the straight than with the humped posture, it means that this applied to all female and/or male speakers alike.

Based on that, the most important points to note from the summary in Figure 4 are that our results *do* show systematic differences between the humped and the straight posture and that these differences were *not* identical for our subsamples of male and female speakers.

The top panel of Figure 4 shows that the posture effects within the male speakers' subsample relate to exponents of pitch, intensity, and fluency. The most salient posture effect concerns the average f0 range, i.e. the difference between the lowest and highest voice-pitch levels in the vocal performances of the 'Rainbow Passage'. This f0 range is almost 10 % higher in combination with the straight than with the humped posture. More specifically, it increases by about 2 semitones from 26.8 semitones in the humped condition to 28.9 semitones in the straight condition. So, the straight posture made the male speakers' speeches more melodious. Moreover, Figure 4 shows that this is increase mainly relies on the f0 maxima, which are on average about 20 Hz higher in the straight condition (161 Hz) than in the humped condition (141 Hz).

The variability (standard deviation) in intensity was, with on average about 32.3 dB, also almost 10 % higher in the male speakers' straight-posture performances than in their humped-posture performances, for which we measured on average only about 30.0 dB intensity variability. Altogether, the differences in f0 range, f0 maximum, and intensity variability suggest that the common underlying change relates to sentence stress. That is, it seems that the straight posture enhanced in the male speakers' speeches the contrast between unstressed and stressed words. The latter were pronounced more strongly and with higher pitch-accent peaks.

The last posture effect that characterized all male speaker alike concerned the frequency of occurrence of silent pauses (> 100 ms). On average, there were about 10 % fewer silent pauses in the straight-posture performances than in the humped-posture performances. In terms of absolute numbers, this means 70 pauses in the former as compared to 78.5 pauses in the latter performances. Pause duration itself did not change from the straight-posture to the humped-posture performances, though. In both conditions, pauses were between 480-540 ms long.

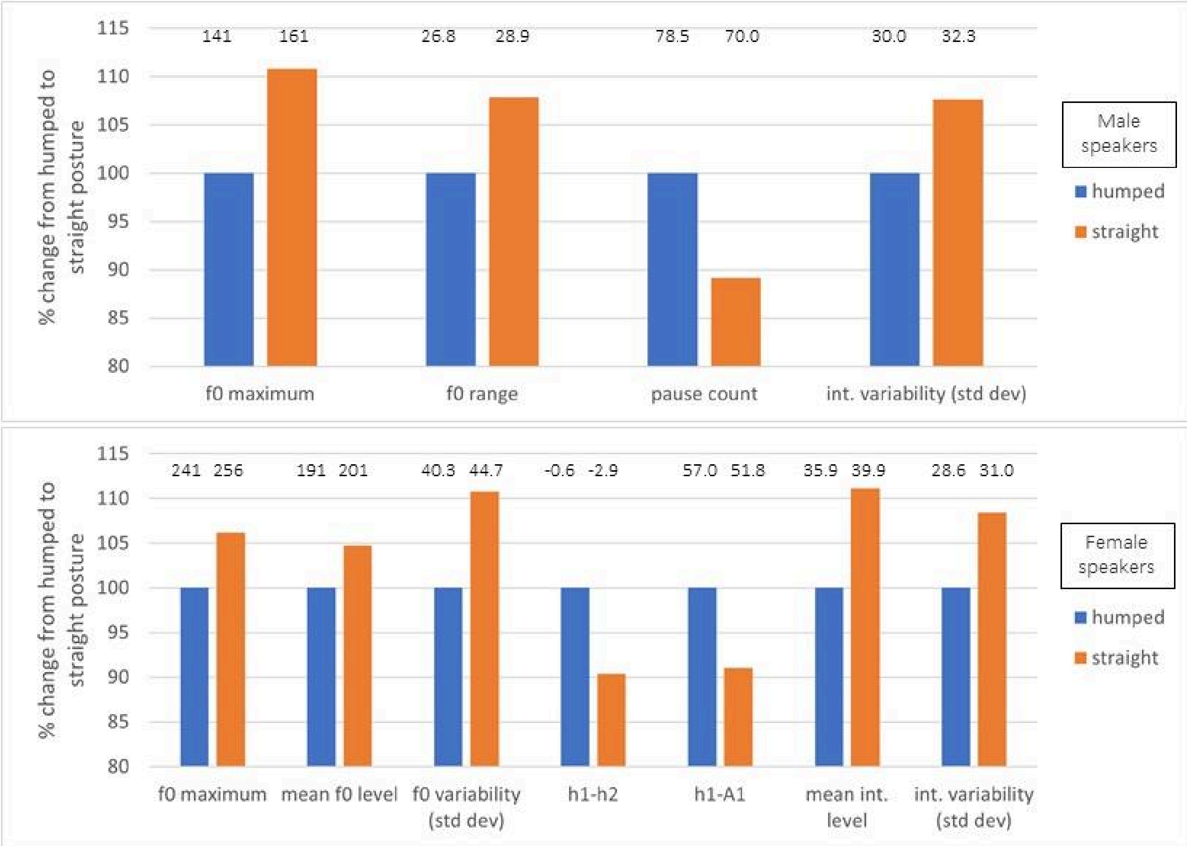

Figure 4 – Prosodic differences (in %) between humped (blue) and straight (orange) vocal performances, displayed separately for the male (top) and female (bottom) speakers' speeches. Absolute measurements are provided above the individual bars in Hz (f0), st (f0 range), count (pause), or dB.

The female speakers' results are depicted at the bottom of Figure 4. The first obvious result is that more prosodic parameters were affected by posture than for the male speakers. The types of affected parameters differed as well. We see increases in f0 variability (standard deviation) by on average more than 10 % from 40.3 Hz in the humped to 44.7 Hz in the straight condition. The mean f0 level also increased slightly (but consistently across all speakers) from 191 Hz to 201 Hz on average. In addition, there is, like for the male speakers' subsample, also a change in the height of f0 maxima and in the intensity variability. Both parameters increased on average by 15 Hz (241 Hz to 256 Hz) or 2.4 dB (28.6 dB to 31.0 dB) from humped to straight posture. So, unlike the male speakers, the female speakers' speeches did not only show more intensity variability and higher and larger pitch movements in combination with the straight posture (together indicative of more pronounced pitch-accent and sentence-stress realizations). They were also overall characterized by *more* pitch movements when a straight posture was adopted.

Furthermore, we found notable effects of posture on voice quality and voice intensity in the female speakers' subsample. Both H1-H2 and H1-A1 strongly and consistently decreased from the humped to the straight posture, i.e. from -0.6 dB to -2.9 dB or from 57 dB to 51.8 dB, respectively. At the same time, the mean intensity level increased by more than 10 % or 4 dB from 35.9 dB to 39.9 dB. Together, this means that the female speakers' voices were overall less breathy and more sonorant, modal, and powerful in the straight-posture performances. This change in voice quality also fits well with the straight condition's higher voice-pitch (f0) level.

6 Discussion and outlook

The preliminary, but in view the consistent difference also clear conclusion must be: Yes, rhetorical trainers and guidebooks seem right. There probably are posture-related effects on the vocal performance of speakers – at least when sitting. The fact that such differences have not been found before [7,8] may be due to the fact that previous speech-elicitation tasks were very artificial and uncommunicative, whereas here the speakers were given a communicative, audience-oriented presentation task. It has already been shown in connection with Lombard speech that such a different communicative embedding can significantly change speaking behavior and, thus, the acoustic analysis results [17].

Compared to a humped posture, a straight posture makes the vocal performance more melodic, fluent, and contrastive or syntagmatically structured in terms of sentence stress and pitch-accent strength. In addition, a straight posture makes the voice louder and more sonorous, at least for female speakers. That the male speakers showed no such changes could be due to the fact that female speakers rely more on abdominal breathing in public speaking than male speakers [16]; and, while sitting, abdominal breathing is likely to be more strongly impeded by a humped posture than chest breathing, which prevails in male speakers' public speeches. A similar causal chain is postulated in the book by [18:155] on public speaking: "Good communication begins with a good starting posture. [...] A good straight posture is the foundation of good breathing. [...] Effective breathing is important for an effective, pleasant speaking voice. Try to project your voice with a slouched posture – it is not possible." The latter blanket statement is an obvious exaggeration, at least it its generalization to both speaker genders. In addition, [16] provided empirical evidence that (the mode of) breathing actually plays a minor role in vocal performance. But if posture not just accompanies but rather hinders speech breathing, then this may be one of the few conditions (also not examined by [7,8]), in which posture, besides its assumed indirect mindset "coloring", also has a direct effect on speakers' phonetic output.

Irrespective of this interesting open question, all posture-induced prosodic changes found here are associated with a more charismatic, i.e. a more attention-attracting and persuasive voice [19]. It can therefore be assumed that a straight posture (while sitting) does indeed increase speaker charisma. Thus, our initial pilot data support the creation and application of the INPOCO system; not only as a research instrument for investigating posture-prosody links in the speech sciences, but also – and maybe above all – as a feedback instrument in public-speaking training. For example, warning speakers through vibration not to sit too hunched over in video meetings can have a positive effect on the speakers' impact and persuasive power.

In addition to the obvious need to expand the speaker sample of the present pilot study, future research should also include a perception experiment. In [7,8], listeners were unable to identify or discriminate posture differences based on audio-only stimuli. This could be different for the data elicited here for the straight vs. humped posture difference. In addition, future research should also investigate articulation parameters and inter-individual differences. If, as suspected, the prosodic-posture effects measured here do not have a physiological or biomechanical origin, but rather represent a postural "coloring" of the speaker's mindset, then pronounced articulatory and inter-speaker effects are to be expected. – Finally, besides these scientific steps, parallel applied steps must be taken to test which feedback sensitivity thresholds are suitable for which speakers in which contexts, and whether the feedback itself can be further refined, e.g., in the form of a successive increase in vibration amplitude.

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