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The Effects of "Media Tech Neck": The Impact of Spinal Flexion on Cognitive and Emotional Processing of Videos

Lucía Cores-Sarría[1*], Jingjing Han[2*], Jessica G. Myrick[3], and Robert F. Potter[4]

Abstract

Adoption of mobile devices (e.g., smart phones and tablets) has popularized a neck-down posture during media consumption that is different from the traditional upright body posture for video viewing. A neck-down posture exerts substantial pressure upon the spine, and this posture has been previously linked to psychological effects. This study advances the literature by studying the impact of posture effects on processing audiovisual information. In a mixed design experiment ($N = 87$), the effect of neck posture when viewing 24 video PSAs was tested using physiological and self-report measures. Multilevel modeling analyses of heart rate and corrugator data showed that spinal flexion lowered attentional engagement and caused incongruent emotional responses to the messages compared to a neutral spine posture. However, spinal-flexion participants exhibited greater skin conductance, counter to the predicted emotional disengagement. The impact of neck posture on message processing was largest at the beginning of the experiment and faded over time.

Keywords

spinal posture, information processing, mobile devices, embodied cognition, engagement

[1]University of Southern Denmark, Odense, Denmark
[2]Fudan University, Shanghai, China
[3]Pennsylvania State University, State College, USA
[4]Indiana University Bloomington, Bloomington, USA

*These authors contributed equally to this work.

Corresponding Author:
Lucía Cores-Sarría, University of Southern Denmark, Campusvej 55, 5230 Odense, Denmark.
Email: lcsa@sdu.dk

Walk around any university campus, shopping mall, busy downtown, subway station, or airport and you will observe many people looking down at their mobile communication devices, busily engaged in activity. Some will be texting, others gaming, and many will be watching video—be it short TikTok posts, news stories, or full-length feature films. Much has been written about the societal implications of the mobile media revolution, yet an underexplored consideration is the impact of body posture on user responses to videos when using mobile devices. Researchers in other fields have noted that the body posture associated with a downward-bent neck, often called "tech neck," is associated with increased physiological stress as well as decreases in confidence and even pain tolerance (e.g., Carney et al., 2015). Given this relationship between neck posture and bodily responses, the present research explores the potential cognitive and emotional effects of watching video with our neck, or cervical spine, in flexion compared to the neutral posture which is more typical of viewing a traditional television, desktop computer, or movie screens.

The Ubiquity of Mobile Media and "Tech Neck"

More than half of Americans own a tablet device and 85% own a smartphone (Pew Research Center, 2021). The increasing ubiquity of mobile devices has caused a fundamental change in the way audiences receive and consume video messages. Usage varies by age, with teenagers in the United States spending an average of 7 to 8 hours consuming entertainment media including TV and online videos, gaming, and social media. Over 75% of that time—approximately 6 hours a day—is spent looking at mobile devices (Rideout & Robb, 2019).

Indications that much of the time spent with mobile devices is in a posture of spinal flexion include an increase in the physical malady medical professionals have named "tech neck." Tech neck is a strain in the neck muscles and upper spinal vertebrae due to the added 10 to 60 pounds (4.5–27 kg) of additional force applied to the cervical spine when the head is flexed downward to look at a mobile device below mid-chest level (Hansraj, 2014).

Data guiding much of what we know about the human cognitive and emotional response to videos were collected using research protocols where audio/visual stimuli were seen by participants sitting in a neutral spine position (Lang, Bolls, et al., 1999; Reeves et al., 1999; Thorson et al., 1985). Due to the prevalence of spinal flexion posture in mobile media use, it is of great importance to understand whether the real-world change from neutral spine to spinal flexion posture alters message processing, and if it does, what the alteration entails for media production and persuasion. Psychophysiological measures can help us assess real-time responses from users' own bodies as they view media with their neck down versus straight. In this study we aim to explore the cognitive and emotional effects of spinal flexion while viewing mediated messages on mobile devices—effects beyond the sore neck muscles associated with "tech neck." We theorize that watching videos in a posture of spinal flexion alters the ways in which the messages are cognitively and emotionally processed, when compared to viewing the same messages in a neutral spine posture.

Theoretical Approach

This research is guided by several postulates of Lang's Dynamic Human Centered Communication Systems Theory (DHCCST; Lang, 2014). Firstly, human cognition is embodied, meaning that the motor and perceptual systems of the body can influence the cognitive ones. In other words, where the body is in space and what it is perceiving, shapes how one thinks and feels, often without conscious awareness. When cognitive processes happen without conscious control, we call it an automatic process (Lang, Potter, et al., 1999). One of the key assumptions of DHCCST is that humans exhibit automatic responses to mediated content just as we do in response to material things—as Reeves and Nass (1996) argued, "Media equals real life." For example, when watching a video of a sexually attractive person on a computer screen, your body automatically responds—at least initially—as if you were seeing the person in the same room as you. The same is true for a video of something repulsive or frightening, like excrement or spiders. For most of human existence, things perceived in the environment were actually there, not mediated through a phone, tablet, or desktop. Therefore, the automatic, subconscious perception of mediated stimuli by our embodied cognitive system results in responses analogous to those we would expect if the stimuli were actually in our immediate proximity.

A third key component of the DHCCST is the existence of two motivational systems (Cacioppo & Berntson, 1994). The appetitive motivational system entices us toward things of benefit while the aversive motivational system has evolved to propel us away from sources of potential danger and harm, like bodily waste and creepy things. These systems are independent of one another, so four states are possible: one where the appetitive system is dominant (approach), one where the aversive system is dominant (avoid), a state of inactivity where the two systems are both low in activation, and a state of coactivation where they both are activated.

A final DHCCST assumption which the current study applies is that human beings have evolved to prefer states of low energy expenditure, favoring situations of low resource allocation—cognitive, nutritional, or otherwise—over large energy outlays (Lang & Bailey, 2015). Given the long timeline of evolution, most of the human arc has been comprised of situations where resource scarcity gave preference to behavior that required as little energy be spent as possible so the rest could be preserved for future important events.

Spinal Flexion Interpreted With DHCCST

Given these assumptions, how does adding the embodied cognitive state of spinal flexion impact cognitive and emotional message processing when viewing video on a mobile device? Spinal flexion is not the typical human posture. *Homo erectus* evolved from earlier quadrupedal ancestors to develop a posture with the "ears aligned with the shoulders and the. . .shoulder blades retracted" (Hansraj, 2014, p. 2), although the set of conditions that gave rise to this postural evolution is a source of debate (Niemitz, 2010). Some hypothesize that it had to do with improved locomotion across changing and unpredictable landscapes (Winder et al., 2015). Others focus on the freeing of the hands to do things like carry infants (Altman & Samuels, 1992; Washburn, 1967), reach to pick food (Jolly, 1970), or carry food once it was obtained (Hewes, 1961). Jablonski and Chaplin (1993) argue that standing upright provided evolutionary benefits through physical dominance, display of power, confidence, or novelty to gain interpersonal advantage. This last theory is mirrored in social psychology literature exploring the effects of the "Power Pose" (Carney et al., 2010; Cuddy et al., 2015). In a systematic review, Carney et al. (2015) found that over 30 studies have demonstrated positive effects of expansive posture on psychological states (e.g., increased feeling of power, pain tolerance, persistence, and self-esteem).

Regardless of the circumstances that facilitated the transition to it, the underlying result is an overall reduction in energy required by the neutral spine posture. This is because "the long axes of the lumbar vertebrae are close to the perpendicular line through the center of gravity. . .Because of the saving of force which bring this about, *the postural back muscles can reduce their expenditure of energy*. . ." (Putz & Müller-Gerbl, 1996, p. 210, emphasis added). In the contrary posture of spinal flexion, not only is more energy required, but an increase in physical stress is applied to the spine—up to 60 additional pounds (27 kg) of force as estimated by Hansraj (2014). So, from the embodied cognition approach of DHCCST, keeping the body in a posture of spinal flexion is more stressful, expends more energy, and is therefore more facilitating of aversive motivational states, than holding the body in a neutral posture.

Furthermore, DHCCST conceptualizes viewing media messages as a dynamic interaction between the message, the body, and the mind, so the impact of spinal position on information processing could interact with the content of the message. Riskind's *appropriateness hypothesis* (Riskind, 1984; Riskind & Gotay, 1982) provides a view congruent with DHCCST by offering an explanation as to why and how the motivational states elicited by spinal posture and message content might interact. The appropriateness hypothesis posits that a posture of slumping shoulders and downward tilting of the neck is "appropriate" in negative contexts because it benefits the individual through emotional self-regulation and protection from overly negative contexts. Similarly, a neutral, upright posture is appropriate in a positive context because it maximizes information intake, which is beneficial in a favorable environment. The appropriateness hypothesis also posits that when posture and situational valence are not matched, the individual is in a maladaptive state of "response competition" which could impede appropriate behavior and lead to helplessness. The appropriateness hypothesis has received empirical support (Körner et al., 2021; Turan, 2015). For example, subjects confronted with a stressor task were found to be better able to regulate cortisol if they were in a submissive posture compared to a dominant posture (Turan, 2015). However, the robustness of the appropriateness hypothesis is a point of debate in the field of social psychology (see Elkjær et al., 2022 for a review).

Based on these two complementary theoretical views of posture effects, we expect that the impact of viewing posture will depend on the appropriateness or congruity of the spinal position for the given mediated context, that is, whether posture facilitates a motivational state that matches or clashes with the motivational state elicited by the message content. As predicted by DHCCST, the added stress and energy expenditure elicited by spinal flexion should place the individual in a more aversive state. However, the appropriateness hypothesis predicts that this state is more appropriate in the context of processing negative messages because it might facilitate a defensive response through disengagement with the content of the message. Similarly, DHCCST expects that an upright, neutral spine places the individual in an appetitive state that facilitates information processing. Under the appropriateness hypothesis, this would be beneficial if the message content itself is positive. However, if spinal posture does not appropriately match the motivational context created by the message, the individual might be prompted to react in a maladaptive way by either engaging too deeply with a negative message in the neutral spine posture or failing to process a positive one in the spinal flexion posture.

Attentional and emotional experiences of media users are two central dimensions of message engagement (Cho, 2013; Smith & Gevins, 2004; Sukulla et al., 2016). In a media context, attention is a psychological construct that describes the perceptual and cognitive engagement of the viewer with the information from the message, often at the cost of decreasing the perceptual and cognitive engagement with the viewer's immediate physical environment. Heart rate (HR) is recognized as a physiological correlate to fluctuations in attention. When processing audiovisual messages, increases in attention result in decreases in both phasic and tonic HR (Potter & Bolls, 2012; Wise, 2017). The phasic analysis of heart rate focuses on the elicitation of an orienting response (OR), an automatic response caused by a novel or a signal stimulus in the environment. The tonic analysis, on the other hand, is used to reflect dynamical attentional process across the entire message. The current study uses the tonic analysis of heart rate to indicate changes in attention.

Emotional intensity, or arousal, is measured by electrodermal activity (EDA) (Potter & Bolls, 2012) with greater EDA suggesting greater emotional arousal associated with intensity of motivational system activation. Regarding the valence of the emotional response, facial electromyography (fEMG) can be used to measure activation of the corrugator muscle located above the eyebrow. Corrugator activation indicates an aversive response, and conversely, corrugator deactivation indicates an appetitive or positive response (Read, 2018).

This study combines response patterns across the three psychophysiological measures to draw conclusions about attention and emotional responses to media interactions. For example, a viewer who experiences message disengagement is likely to exhibit a physiological response pattern with faster HR, lower EDA, and high or low corrugator activation depending on the affective tone of the message content: less engagement with negative messages should result in low corrugator activity, but less engagement with positive messages should result in high corrugator activity.

Complementary to the physiological profile described above, a viewer who experiences disengagement during message viewing is expected to self-report less attention and less emotion, that is, lower self-reported arousal and lower positivity (for positive messages) or lower negativity (for negative messages).

Holding the neck in a posture of spinal flexion is aversive due to the increase in physical stress. We expect this negative state will lead to attentional disengagement from processing the video messages. Thus,

H1. When viewing the video, those in the spinal flexion condition will exhibit faster heart rate and lower self-reported attention compared to those in the neutral spine condition.

Because fewer processing resources are expected to be allocated by viewers in a spinal flexion posture, they are also expected to be more emotionally disengaged, that is, less affected by the emotional valence of the message content. Thus, the second general hypothesis is a main effect of spinal posture on emotional engagement, with specific predictions depending on the dependent variable being considered. First, the comparative lack of engagement with message content will lead to less predicted arousal for those in the spinal flexion condition, regardless of message valence they are exposed to. Therefore,

H2a: When viewing the video, viewers in the spinal flexion condition will have lower EDA and lower self-reported arousal than those in the neutral spine condition.

Corrugator muscle activity and self-reported valence are expected to demonstrate interaction effects between spinal posture and message valence. Spinal flexion is expected to put the body in a negative state, which in the context of negative message viewing is advantageous for emotional regulation per the appropriateness hypothesis. By matching the valence of the message, spinal flexion should result in emotional disengagement, leading to a less negative state for participants in that condition, compared to those with a neutral posture. Furthermore, due to the boost in emotional regulation, participants are also expected to report a more positive state. Thus,

H2b: Those viewing negative messages in the spinal flexion condition will have less corrugator activation while viewing, less self-reported negativity, and higher self-reported positivity compared to those in the neutral spine condition.

The opposite reaction is expected when processing positive messages in a spinal flexion posture. Because of the aversive state caused by the posture, and the reduction in content processing predicted by both DHCCST and Riskind's appropriateness hypothesis in such a context, it is predicted that:

H2c. Those viewing positive messages in the spinal flexion condition will have greater corrugator activation during viewing, higher self-reported negativity, and lower self-reported positivity than those in a neutral spinal posture.

The dynamic nature of communication is of special relevance here because the embodied effect of spinal posture is likely to be affected by time, as the stress on the muscles exerted by spinal flexion should be magnified by longer media exposures. As a result, this could expand the gap between the attentional and emotional effects of the two postures. That is, spinal posture effects could be larger at the end compared to the beginning of media exposure. Alternatively, even though neutral spine offers a more natural and efficient posture than spinal flexion, it still requires the viewer to stay immobile in a sitting position, which could become uncomfortable over the course of an experimental session. From that perspective, the benefits of a neutral spine could be diluted over time, with participants increasingly experiencing an aversive state and message disengagement just like those in spinal flexion. In other words, the impact of the two postures could converge as time goes on. To test this, two different time dimensions were conceptualized in this study that could modulate spinal posture effects: the time within any given message (i.e., message time, from stimulus onset to the end of each message), and the overall duration of the experimental session (i.e., exposure time, from the beginning of the first message to the end of the last message of this experiment). Based on this, we asked:

RQ1. Do spinal posture effects increase or decrease as a function of message time or exposure time?

Method

Design

This study employed a 2 (Spinal posture: neutral, flexion) × 2 (Message valence: positive, negative) × 2 (Message arousal: low, high) × 2 (Video topic: sexual health, safe driving) × 3 (Message repetition) mixed-design. Spinal posture was a between-subjects condition and the rest were within-subjects factors, resulting in a total of 24 messages. The analyses also included message time and exposure time variables to account for duration of the individual message and the experimental protocol, respectively. The stimuli were identical to ones used in another study (Han & Zheng, 2017) which employed a 2 (Message valence: positive, negative) × 2 (Message arousal: low, high) × 2 (Video topic: sexual health, safe driving) × 3 (Message repetition) within-subjects design. Although message arousal was not a main focus of the current study, we preserved the message arousal variable in the design and the analyses to both control for arousal effects and to improve message generalizability.

Procedure

Data were collected from participants during individual sessions, as approved by the IRB. Participants in the flexion condition sat in a chair in front of a mobile device stand which contained a standard-sized iPad 2 positioned just above a Tobii TX60 eye tracker. In order to view and interact with the mobile device, the participant needed to tilt their head downward at approximately a 45° angle. Participants in the neutral spine condition viewed the stimuli on the same iPad attached to an unilluminated computer monitor placed on the desk and raised to a height such that the participant could sit and watch the stimuli in a neutral spinal position, at roughly a 90° angle to the floor. Because the two levels of the spinal posture factor required physical reconfiguration of the laboratory space, data were collected from spinal flexion participants first.

After a short verbal description of the procedure, the researchers attached physiological electrodes to the participant's forearms, palm, and face. The spinal flexion angle was measured for both between-subjects conditions using a goniometer, after asking the participant to look at the tablet in a natural manner. Afterwards, the researcher moved to the other side of a partition and gave eye-tracking calibration instructions to the participant. The chair and device stand were adjusted when needed to assure identical eye tracking settings across participants. Before data collection started, participants watched a grey screen for 3 min during which they were told to relax and clear their mind.

Participants watched the 24 PSAs, randomly presented by Qualtrics software, and completed several brief self-report questions after each. Prior to each PSA, a grey screen was presented for 5 s to allow subjects to return to an emotional and cognitive baseline. After all the PSAs were viewed, the electrodes were removed the participant was taken to another room where they completed a recognition memory task. After that, participants were thanked and dismissed.

Participants

Undergraduate students ($N=87$, 42 for the spinal flexion condition and 45 for the neutral spine condition) participated in exchange for course credit. The average age was 21 years ($SD=1.16$, range 18–24). Most participants reported being White (79.4%). Others identified themselves as Asian (10.3%), Black (4.6%), and more than one race (4.6%). Most participants reported their gender as female (64.4%). All provided informed consent before commencing the data collection and none discontinued participation once the procedures began. Due to technical problems five participants' physiological data were missing. As a result, 82 participants' data were used for the physiological analyses.

Stimuli

The stimuli were 24 video public service announcements (PSAs) selected to completely cross the message valence, message arousal, and video topic factors. In the Han and Zheng (2017) study, undergraduate students ($N=37$) from the same university watched the videos in a neutral spine position and rated how positive, negative, and emotionally aroused each video made them feel using 9-point scales. Results from these rankings served as stimulus confirmation for the current study. Positive videos contained sexually appealing content (e.g., attractive people kissing, a bedroom scene), scenes of holiday celebrations, or humor. Negative message content included accidents, blood, and illness, for example. The stimuli can be found at https://osf.io/ubfq9/. The range of stimuli duration was 30 to 42 s, with most being 30 s.

Self-report data from the current study were analyzed using repeated measures ANOVA revealing significant main effects of message valence for both self-reported positivity ratings (F[1, 86] = 637.57, $p < .001$, $\eta_p^2 = .88$) and negativity ratings (F [1, 86] = 491.56, $p < .001$, $\eta_p^2 = .85$). Positive videos were rated significantly more positive ($M = 5.35$, $SE = .11$) and less negative ($M = 2.55$, $SE = .11$) than negative videos ($M_{positivity} = 1.84$, $SE_{positivity} = .09$; $M_{negativity} = 6.28$, $SE_{negativity} = .17$). Results also show a main effect of message arousal on self-reported arousal, F[1, 86] = 158.25, $p < .001$, $\eta_p^2 = .65$. High arousing videos ($M = 4.87$, $SE = .17$) were rated significantly higher than low arousing videos ($M = 3.92$, $SE = .16$). There was no message valence main effect ($p = .30$) nor message valence by message arousal interaction ($p = .90$) in self-reported arousal. The selected videos were later coded by three coders for structural complexity (i.e., information introduced per camera change, see Lang et al., 2007), with no significant differences found across any factor in the number of such features.

Independent Variables

The main variables of interest were spinal posture and message valence. A second-by-second *message time* variable was included as an independent variable of interest for the physiological measures to account for changes during each message. The *exposure time* variable was created for each subject by coding the messages from 1 to 24 in the order of presentation. Message arousal and video topic were included as covariates in the statistical analyses to improve generalizability to a wide range of messages with varying levels of arousing content.

Dependent Variables

Attention. Heart rate (HR) calculated offline from the electrocardiogram (ECG) was used as a physiological indicator of attention. ECG was recorded with bipolar and ground electrodes attached to participant's forearms. ECG signals from three participants were lost during data collection due to equipment malfunction, resulting in $N = 79$ for heart rate. After visually identifying noise artifacts, 0.3% of beat-per-minute (BPM) values were mean replaced using valid values obtained immediately before and after the artifact. Top-down, introspective aspects of cognitive activities were measured on three 7-point scales. The first measured the attention paid to the message, from 1 (*not at all*) to 7 (*very much*), the second measured how interesting they found the message, from 1 (*not at all*) to 7 (*very interesting*), and the third measured how much thought they put into evaluating the message, from 1 (*not at all*) to 7 (*a lot*).

Emotional Arousal. EDA was measured from the palm of participants' non-dominant hand. Skin Conductance Level (SCL) data were aggregated at 1-s intervals and visually inspected using Acqknowledge software. EDA signals from three participants were lost during data collection due to equipment malfunction, resulting in $N=79$ for these analyses. Motion artifacts were visually identified and removed by calculating the average value between the two adjacent points within normal range. Self-reported arousal was measured on a 9-point scale ranging from 1 (*not at all aroused, not at all excited, not at all awake*) to 9 (*extremely aroused, excited, awake*) for arousal (Lang et al., 2005, 2011).

Emotional Valence. fEMG was recorded from the corrugator supercilii muscle area above the subject's left eyebrow. After rectification and integration, data were mean aggregated at 1-s intervals. Visual inspection of the data, and reference to notes recorded by the experimenter during data collection, resulted in identification of invalid fEMG data for 27 subjects. Reasons for this varied (e.g., imprecise placement of electrodes leading to cross talk with other physiological signals, high impedance in the signal) but removal of invalid fEMG data prior to analysis is not uncommon (Potter & Bolls, 2012; Sae-lim et al., 2018). This resulted in a total of 28 participants in neutral spine and 24 participants in the spinal flexion condition included for the fEMG analyses. Self-reported valence was measured on two 9-point scales, a positivity scale ranging from 1 (*not at all positive, not at all happy, not at all pleased*) to 9 (*extremely positive, happy, pleased*) and a negativity scale ranging from 1 (*not at all negative, not at all unhappy, not at all annoyed*) to 9 (*extremely negative, unhappy, annoyed*) for negativity (Lang et al., 2005, 2011).

Data Transformations

All physiological data were sampled using Biopac bioamplifiers at 2000 Hz during message exposure and integrated with the eye tracking data with iMotions software. Eye tracking data are not reported here since they do not relate to our hypotheses or question.

The SCL and corrugator data exhibited high variability across participants, a common phenomenon for between-subjects design using psychophysiological measures. Change scores from baseline were calculated for SCL and corrugator by subtracting each data point from the value of the baseline, 1 s prior to message onset (Potter & Bolls, 2012). Corrugator change-score data were then filtered to remove extreme values above 0.2 mV or below −0.2 mV, which were likely due to motion artifact (e.g., sneezing, yawning) instead of the more subtle activation elicited by emotional processing. However, the raw data was used for HR because it is a measure with comparatively little intersubject variability and the analytical strategy adopted assigns separate intercepts to each subject, which accounts for individual differences. To facilitate the interpretation of main effects and interactions, the categorical variables (i.e., spinal posture, message valence, message arousal, and video topic) were effect-coded to −1 and 1. The variables *message time* and *exposure time* were standardized and mean-centered. The shortest stimuli duration was 30-s, which became the time vector for the physiological analyses.

Data Analysis

All data were analyzed using a multilevel modeling (MLM) approach. MLM has recently taken precedence in media psychology research over repeated measures ANOVA as a more appropriate way to analyze hierarchical data such as psychophysiological data (Clayton et al., 2017; Keene et al., 2019; Rasmussen et al., 2017). R software and the *Lme4* package (Bates et al., 2015) were used for multilevel model analysis. The covariance matrix was unstructured. Post hoc comparisons, when necessary, were carried out with the *emmeans* R package (Lenth, 2021) with Tukey corrections for *p*-adjustment.

Each video was seen by all participants, video-related measurements were simultaneously nested within participant and video, thus requiring a cross-classified multilevel model (Judd et al., 2012). All models followed a structure motivated by the hypotheses. The fixed structure included main effects for spinal posture condition, message time, exposure time, and valence, and main effects for the two covariates message arousal and video topic. In order to address the hypotheses and research question, the models also included a 3-way interaction between posture condition, message time and exposure time, which included its lower-level interactions, as well as a 2-way interaction between posture condition and message valence. Variables indexing the progression of time were included as random slopes for both subject and stimuli: message time and exposure time were included as random slopes for the physiological variables, and an exposure time random slope was included for the self-reported variables. The models for the self-reported variables were identical to the physiological models, with the exception that they did not include the message time variable. None of the models gave convergence or singularity problems, so the structures did not require simplification. The analyses, data, and information about power analysis and effect size can be obtained at the following link: https://osf.io/ubfq9/.

Results

Manipulation Check

Our hypotheses assume that flexion, compared to a neutral spine, places the individual in an aversive state due to increased muscular stress and energy expenditure. To check whether the spinal posture manipulation had the expected effect, two different methods were used. First, the goniometric measure shows that the angle of tilt for participants' neck in the spinal flexion group was significantly greater than for the neutral spine group (t[38.10] = 17.64, $p < .001$; ($M_{\text{SpinalFlexion}} = 11.96$, $SD_{\text{SpinalFlexion}} = 4.11$; $M_{\text{NeutralSpine}} = 0.11$, $SD_{\text{NeutralSpine}} = 0.56$). Second, two Likert scales were included at the end of the experiment: a neck pain measure, where participants indicated their current level of neck pain from 1 (*no pain at all*) to 9 (*severe pain*), and a neck strain measure, where participants were asked to rate their agreement with the sentence 'my neck currently feels very strained' from 1 (*strongly disagree*) to 7 (*strongly agree*). Although people in spinal flexion reported higher level of pain than people in the neutral spine condition ($M_{\text{SpinalFlexion}} = 3.05$, $SD_{\text{SpinalFlexion}} = 1.99$; $M_{\text{NeutralSpine}} = 2.43$, $SD_{\text{NeutralSpine}} = 1.65$), this difference was not significant ($t=-1.56$, $p=.122$), but there was a significant effect on how strained participants' necks were, with participants in spinal flexion ($M=4.14$, $SD=1.97$) reporting more strain than participants in neutral spine ($M=3.30$, $SD=1.87$) ($t=-2.04$, $p=.044$). Thus, the experimental manipulation was successful with regards to spinal flexion angle and perceived neck strain.

Effect of Spinal Posture on Attention

Our first hypothesis (H1) predicted that spinal flexion would elicit less attention than a neutral-spine posture, indicated by faster heart rate and lower self-reported attention.

Analysis of covariates in the heart rate data revealed a significant main effect of message time ($\beta=-.32$, $p=.02$), and a significant interaction between the message time and exposure time ($\beta=-.086$, $p=.04$). Heart rate slowed down over time within each video, indicative of increasing attention over the course of the message. In addition, this effect was accentuated as the experimental session went on: later messages showed a steeper effect of message time than those in the beginning of the experiment. None of the other covariates revealed significant effects on heart rate.

In response to H1, spinal posture did impact heart rate, as shown by a significant interaction between posture condition and message valence as well as a significant 3-way interaction between spinal posture, message time, and exposure time (see Table 1). Regarding the effect of spinal posture as a function of message valence, post hoc analysis failed to show a significant effect of spinal posture when considering the isolated effect on negative ($\beta=-.18$, $p=.89$) or positive messages ($\beta=-.36$, $p=.79$). However, post hoc trend analysis (used to test the slope difference of regression lines) indicated a steeper difference between positive and negative messages for participants in spinal flexion compared to participants in neutral spine ($\beta=.18$, $p=.04$). Positive message processing resulted in more heart rate deceleration and therefore greater attention than negative messages, and this was especially the case for participants in the neutral spine.

Using the pick-a-point probing method (Hayes & Matthes, 2009), exploration of the 3-way interaction between spinal posture, message time, and exposure time showed that participants in the two postural conditions differed in attention allocation, with participants in the spinal flexion exhibiting faster heart rate and therefore lower attention than those in the neutral spine. Nevertheless, this posture effect on heart rate decreased and eventually disappeared towards the end of the experiment (see Figure 1 and Table 1, the first message: $\beta=-.75$, $p=.003$; ninth message: $\beta=-.4$, $p=.04$). This result offers partially support towards H1, as spinal flexion was comparatively detrimental for attention compared to a neutral spine, but only in the first portion of the viewing session. Additionally, these results also shed light on RQ1, which asked whether duration of an individual message or the experimental procedure itself had an impact on the effects of spinal posture. When it comes to attentional disengagement, the beneficial effect of a neutral spine over spinal flexion decreased and eventually disappeared with longer exposures to message processing.

Table 1. Multilevel Modeling Results of Heart Rate.

Predictors	β	*SE*	*CI*	*t*-Value	*df*	*p*-Value
(Intercept)	79.23	1.35	76.57–81.88	58.48	78.70	<**.001**
Message time	−.32	0.14	−0.59 to −0.05	−2.34	61.90	**.022**
Spinal posture	−.27	1.35	−2.91–2.37	−0.2	77.00	.842
Message valence	−.18	0.14	−0.45–0.08	−1.35	20.00	.189
Message arousal	−.18	0.14	−0.45–0.09	−1.32	20.00	.200
Video topic	.12	0.14	−0.14–0.39	0.91	20.00	.375
Exposure time	−.06	0.19	−0.43–0.30	−0.33	52.90	.740
Spinal posture × mess. time	−.16	0.11	−0.37–0.05	−1.53	71.10	.131
Spinal posture × mess. valence	−.1	0.04	−0.18 to −0.01	−2.17	53,900.00	**.030**
Spinal posture × exp. time	.05	0.13	−0.20–0.30	0.39	72.80	.699
Mess. time × exp. time	−.09	0.04	−0.17 to −0.00	−2.03	54,400.00	**.042**
Spinal posture × mess. time × exp. time	.13	0.04	0.04–0.22	2.97	51,900.00	**.003**
ICC			0.58			
N_{ID}			79			
N_{Stim}			24			
Observations			55,520			
Marginal R^2/conditional R^2			.001/.584			

Note. Bold values indicate results where p < .05. See random effects on our OSF page.

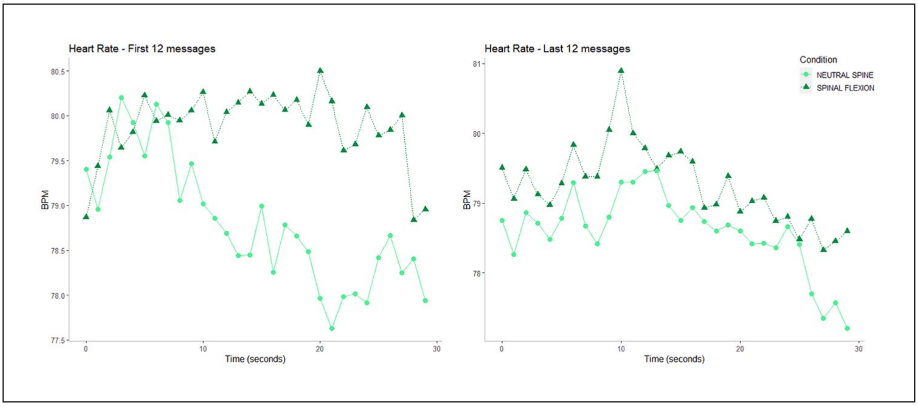

Figure 1. Spinal posture × exposure time × message time interaction on heart rate.
Note. BPM on the *y*-axis means beat-per-minute, the unit for heart rate. Lower BPM means heart rate deceleration suggesting a higher level of cognitive engagement or attention.

Results of self-report data failed to show a significant effect of spinal posture on the participants' perceived cognitive experiences (see Table 4). Participants in both posture conditions reported similar levels of attention and interest in the content of the message and expressed similar levels of thoughtfulness when evaluating the video.

Additionally, these measures were sensitive to other aspects of the stimuli, as expected. There was a significant effect of message arousal on all three measures, with high arousing messages eliciting greater self-reported attention, interest, and thoughtfulness than low arousing messages. Similarly, message valence impacted two of those self-report measures, with negative messages receiving more attention and more thoughtfulness than positive messages.

Effect of Spinal Posture on Emotion

Our second group of hypotheses predicted that spinal flexion would result in less emotional engagement than a neutral-spine posture. We explore these across the two primary dimensions of emotion.

Emotional Arousal. H2a predicted lower SCL for participants in spinal flexion as an indication of less emotional arousal. Analysis of the SCL data revealed a main effect of spinal posture and a significant interaction between spinal posture and message time qualified by a significant 3-way interaction between spinal posture, message time, and exposure time (see Table 2). Contrary to H2a, spinal flexion resulted in a higher level of SCL and thus greater physiological arousal than a neutral spine, as shown by post hoc testing of the posture condition by time interaction ($\beta = 7.07$, $p = .04$). While SCL increased over the duration of a message for the participants in spinal-flexion posture ($\beta = 6.07$, $p = .03$), it remained rather flat during the processing of messages in a neutral-spine posture ($p = .71$) (see Figure 2).

Furthermore, this interaction was affected by the duration of exposure to message processing. Pick-a-point probing of the 3-way interaction indicated that during the first half of the experimental procedure SCL increased for those in a posture of spinal flexion but not for those in a neutral-spine posture (message 12: $\beta = -7.07$, $p = .037$). However, the difference between the two conditions decreased as the experiment continued, and by the end of the protocol the SCLs in both posture conditions were no longer different from each other, both exhibited negative time trends (message 24: $\beta = 5.76$, $p = .16$). Thus, contrary to H2a, spinal flexion led to more physiological arousal than a neutral spine, and answering RQ1, this effect faded over time.

In addition, our self-report data showed a trend consistent with the physiological findings. Spinal flexion participants rated messages as more arousing ($M = 4.52$, $SD = 0.27$) than participants in the neutral spine condition ($M = 4.07$, $SD = 0.26$), though the difference did not reach statistical significance ($\beta = -.22$, $p = .17$).

Emotional Valence. H2b and H2c predicted that spinal flexion would result in lower positive and higher negative responses for positive messages, and lower negative and higher positive responses for negative messages, compared to the neutral spine condition. The effect of spinal posture on emotional valence was tested physiologically with data from the corrugator muscle (where activation in the corrugator is an index of negativity and deactivation an index of positivity) and through self-report with the positivity and negativity scales.

Results showed a significant main effect of message valence on corrugator activity qualified by a significant 2-way interaction between spinal posture and message valence (see Table 3). The main effect of valence revealed lower corrugator activation during negative messages than during positive messages, contrary to what one would expect. However, the 2-way interaction indicates that this was primarily led by the spinal flexion condition. Post hoc analysis confirmed that there were significant differences in corrugator activation across the two spinal postures for positive and negative messages ($\beta = 2.34$, $p < .001$) (see Figure 3). Participants in a posture of spinal flexion exhibited less corrugator activation ($M = -4.09$, $SE = 1.15$) when viewing negative messages than those in a posture of neutral spine ($M = -0.54$, $SE = 1.11$) ($\beta = 1.70$, $p < .001$), thus supporting H2b. For positive messages, participants in the spinal flexion posture exhibited higher levels of corrugator activation ($M = 0.94$, $SE = -0.65$) than the neutral spine ($M = -0.33$, $SE = -1.11$), as hypothesized, but this effect was not significant ($\beta = .64$, $p = .20$), thus H2c was not supported.

Analyses of the self-report data yielded ambiguous results. Although there were significant interactions between spinal posture and message valence for both the positivity and negativity scales (see Table 4), post hoc testing did not confirm any significant effects of spinal flexion for either positive or negative messages. Instead, trend analyses suggested that the interaction was driven by a difference in the slopes across conditions. Specifically, positive messages were evaluated as more positive and less negative than negative messages, as one would expect, and this difference was steeper for participants in the neutral spine condition than for participants in spinal flexion, in both the positivity ($\beta = -.167$, $p = .017$) and the negativity self-reported measures

Table 2. Multilevel Modeling Results of Skin Conductance.

Predictors	β	*SE*	*CI*	*t*-Value	*df*	*p*-Value
(Intercept)	11.1	4.87	1.56, 20.65	2.28	78.15	.025
Message time	2.49	2.22	−1.86, 6.84	1.122	58.95	.266
Spinal posture	−9.49	3.87	−17.08, −1.90	−2.452	77.10	**.017**
Message valence	1.57	2.81	−3.93, 7.07	0.559	19.98	.582
Message arousal	−5.57	2.81	−11.07, −0.06	−1.982	19.99	.061
Video topic	0.58	2.81	−4.93, 6.08	0.205	19.99	.840
Exposure time	−7.72	5.33	−18.17, 2.73	−1.448	51.68	.154
Spinal posture × mess. Time	−3.58	1.69	−6.89, −0.27	−2.117	76.72	**.038**
Spinal posture × mess. valence	1.02	0.79	−0.52, 2.56	1.295	56,059.50	.196
Spinal posture × exp. time	2.99	3.33	−3.55, 9.52	0.896	76.94	.373
Mess. time × exp. time	−0.59	0.77	−2.09, 0.91	−0.769	55,013.02	.442
Spinal post. × mess. time × exp. Time	4.11	0.77	2.60, 5.62	5.34	51,911.29	<**.001**
ICC			0.08			
N_{ID}			79			
N_{Stim}			24			
Observations			56,400			
Marginal R^2/conditional R^2			.006/.085			

Note. Bold values indicate results where p < .05. See random effects on our OSF page.

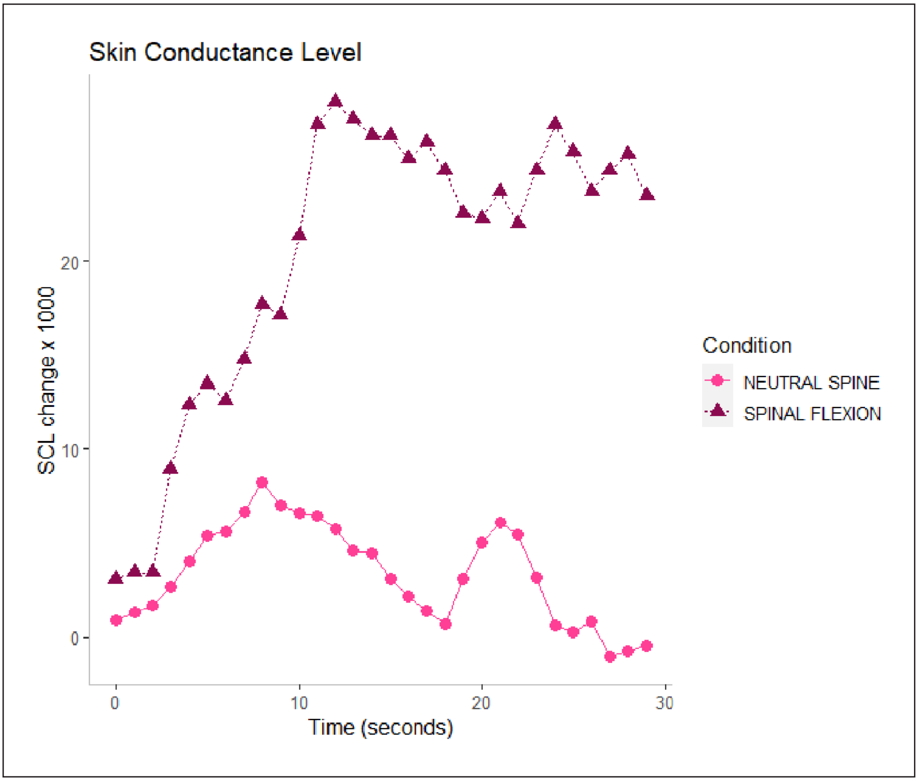

Figure 2. Spinal posture × message time interaction on skin conductance level.
Note. Skin conductance level change scores are scaled up by 1,000 to facilitate visualization.

($\beta = .18$, $p = .019$). Thus, the self-reported measures of emotional valence failed to support H2b and H2c.

Discussion

The widespread adoption of mobile devices (i.e., smartphones and tablets) has popularized a neck-down posture during everyday media consumption that exerts uncomfortable pressure in the flexed spine. From the vantage point of communication theory, such a posture is notably different from the upright or neutral spine posture typically employed in most audiovisual media research. The results from this study—which show differences in response across postures—suggest that communication theories should be revisited and reinterpreted given the different postural world we live in when it comes to media consumption. We found that viewing video messages in a posture of spinal flexion affects cognitive and emotional processing of video messages in a way suggesting message disengagement. This was particularly reflected in the

Table 3. Multilevel Modeling Results of Corrugator Muscle Activation.

Predictors	β	*SE*	*CI*	*t*-Value	*df*	*p*-Value
(Intercept)	−1.03	0.85	−2.69, 0.62	−1.22	36.34	.230
Message time	−.49	0.34	−1.15, 0.17	−1.46	29.59	.156
Spinal posture	.54	0.47	−0.38, 1.47	1.15	50.23	.255
Message valence	1.34	0.56	0.25, 2.43	2.41	19.99	**.026**
Message arousal	−.91	0.56	−2.00, 0.18	−1.64	20.05	.117
Video topic	−.59	0.56	−1.68, 0.50	−1.07	20.05	.298
Exposure time	−.18	0.90	−1.94, 1.58	−0.20	39.78	.842
Spinal posture × mess. time	.31	0.21	−0.10, 0.71	1.48	49.84	.146
Spinal posture × mess. valence	−1.18	0.16	−1.50, −0.86	−7.15	36,743.69	<**.001**
Spinal posture × exp. Time	.93	0.50	−0.05, 1.91	1.86	50.16	.069
Mess. time × exp. Time	.68	0.16	0.37, 1.00	4.26	35,937.48	<**.001**
Spinal post. × mess. time × exp. time	−.27	0.16	−0.59, 0.05	−1.67	30,023.75	.094
ICC				0.05		
N_{ID}				52		
N_{Stim}				24		
Observations				37,200		
Marginal R^2/conditional R^2				.006/.056		

Note. Bold values indicate results where p < .05. See random effects on our OSF page.

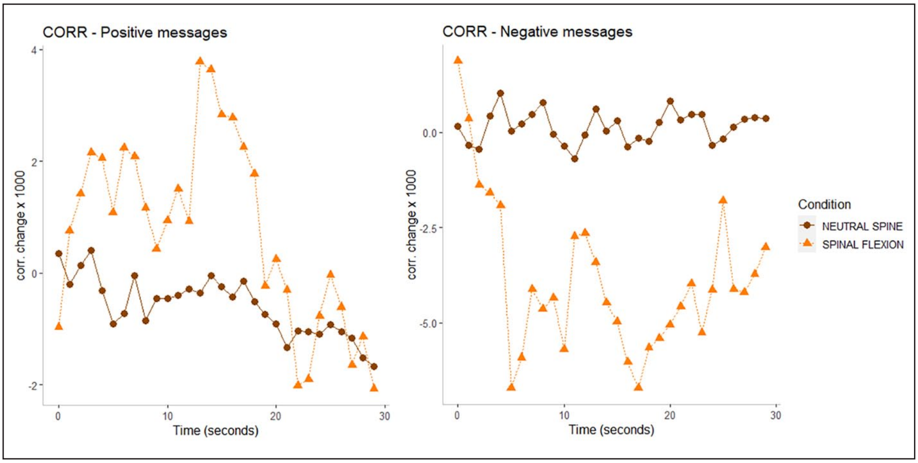

Figure 3. Spinal posture × valence × message time interaction on corrugator activation.
Note. Corrugator activation change scores are scaled up by 1,000 to facilitate visualization.

physiological measures—both cognitive and emotional, but not in self-reported measures of conscious experience.

Based on DHCCST (Lang, 2014) and the appropriateness hypothesis (Riskind, 1984), we predicted that watching videos with a neutral spine would elicit more attention and stronger emotional responses because it is the posture humans evolved to hold themselves in, is more comfortable, and requires less energy. On the other hand, we posited that spinal flexion—which is conceptually a less comfortable posture—could help emotional self-regulation by blocking information intake in negative contexts. Nevertheless, this posture would be detrimental when the task presents positive information. Heart rate data supported this prediction, qualified by the length of media exposure: for approximately the first half of the messages, participants in the neutral spine condition exhibited higher attentional levels, as indicated by greater heart rate deceleration, than those in spinal flexion. However, this effect disappeared towards the end of the experiment.

Corrugator muscle data also supported the predictions. When messages had a negative tone, people in spinal flexion exhibited less corrugator activation and therefore a less aversive response to negative content than those in a neutral spine posture. This finding supports a conclusion that people in spinal flexion experienced disengagement with the message, especially when it protects them from experiencing the distress of processing negative information (e.g., by mental counter-arguing or ridiculing the content of the message). Conversely, participants holding a neutral spine reacted with an emotional response more congruent with the valence of the message. For example, neutral spine participants exhibited less corrugator activation during videos with positive content compared to those watching in the spinal flexion condition, who exhibited more negative physiological responses to positive videos than to negative ones. The fact that self-reported valence results were as expected given the message content

Table 4. Multilevel Modeling Results of Self-Reported Measures.

	β	*SE*	*df*	*t*-Value	*p*-Value
Arousal					
(Intercept)	4.29	0.21	74.30	20.51	**<.001**
Spinal posture	−.22	0.16	79.98	−1.36	.176
Mess. valence	−.09	0.13	20.04	−0.69	.498
Mess. arousal	.63	0.13	20.06	4.65	**<.001**
Video topic	−.14	0.13	20.06	−1.03	.313
Exposure time	−.06	0.05	30.62	−1.30	.204
Posture × valence	.05	0.04	1,823.13	1.28	.200
Posture × exp. time	.04	0.05	80.05	0.89	.377
Positivity					
(Intercept)	3.54	0.17	40.23	21.46	**<.001**
Spinal posture	.05	0.10	80.03	0.51	.610
Mess. valence	1.40	0.14	20.04	10.34	**<.001**
Mess. arousal	.02	0.14	20.06	0.16	.878
Video topic	−.02	0.14	20.04	−0.16	.878
Exposure time	.00	0.05	78.83	−0.03	.975
Posture × valence	.08	0.04	1,831.00	2.39	**.017**
Posture × exp. time	.06	0.05	80.70	1.21	.228
Negativity					
(Intercept)	4.06	0.18	48.49	23.06	**<.001**
Spinal posture	.07	0.12	80.00	0.61	.547
Mess. valence	−1.59	0.14	19.90	−11.64	**<.001**
Mess. arousal	.13	0.14	19.91	0.93	.365
Video topic	−.05	0.14	19.91	−0.38	.710
Exposure time	.09	0.05	78.95	1.99	**.050**
Posture × valence	−.09	0.04	1,842.20	−2.36	**.019**
Posture × exp. time	.05	0.05	80.60	1.07	.288
Attention					
(Intercept)	5.52	0.12	90.90	46.68	**<.001**
Spinal posture	.12	0.10	79.99	1.16	.250
Mess. valence	−.15	0.06	20.02	−2.62	**.016**
Mess. arousal	.23	0.06	20.15	4.03	**<.001**
Video topic	−.04	0.06	20.05	−0.77	.449
Exposure time	−.14	0.04	45.53	−3.66	**<.001**
Posture × valence	.00	0.02	1,818.00	−0.05	.960
Posture × exp. time	.01	0.03	80.64	0.33	.742
Interest					
(Intercept)	4.03	0.13	46.57	30.60	**<.001**
Spinal posture	.10	0.09	79.98	1.18	.241
Mess. valence	−.16	0.10	20.01	−1.58	.129
Mess. arousal	.36	0.10	20.00	3.52	**.002**
Video topic	−.19	0.10	19.99	−1.85	.079
Exposure time	.04	0.04	182.87	1.10	.274
Posture × valence	−.02	0.03	1,855.19	−0.62	.535
Posture × exp. time	.04	0.04	207.80	1.00	.318
Thought					
(Intercept)	5.00	0.15	86.95	34.48	**<.001**
Spinal posture	.15	0.14	80.00	1.06	.291
Mess. valence	−.19	0.04	19.87	−4.76	**<.001**
Mess. arousal	.13	0.04	19.97	3.18	.005
Video topic	−.09	0.04	19.92	−2.14	**.045**
Exposure time	.03	0.04	80.15	0.70	.484
Posture × valence	.01	0.02	1,809.00	0.58	.560
Posture × exp. time	.01	0.04	80.36	0.21	.834

Note. Values with $p < .05$ were bolded.

(e.g., negative messages were rated more negative than positive), combined with the contrary physiological results suggests that participants in the spinal flexion posture consciously recognized the "correct" emotional response given the content, but their facial muscle activity—which is more automatic and uncontrollable—points to more dynamic emotional processing happening at the unconscious level.

The analysis of skin conductance revealed unexpected results. Even though the other two physiological measures suggested more thorough cognitive processing and more congruent emotions for those in a neutral spine, participants in spinal flexion rather than the neutral spine posture exhibited much larger skin conductance levels, which is typically interpreted as indication of a stronger emotional response. When considering all the physiological results together, it suggests that when media consumers are positioned with a flexed spine, they are more sympathetically activated but not cognitively engaged. This is contrary to earlier media research findings where higher sympathetic activation and greater cognitive engagement tend to go hand in hand. Medical and physiology literature can help clarify the unexpected electrodermal and self-reported results. The sympathetic system highly involves the initiation and maintenance of chronic neck pain syndromes, which are usually caused by chronic flexion of the spine (e.g., Falla & Farina, 2007; Passatore & Roatta, 2006). This sympathetic activation supports the increased metabolic requirement, affects muscle fibers' contractility, and modulates the proprioceptive and nociceptive information due to the flexed spine (e.g., Passatore & Roatta, 2006). Therefore, we suspect that the high SCL observed in the flexed-spine participants may be more of a result of increased physiological, rather than cognitive, demand. That is not to say that the SCL data was not a valid indicator of emotional arousal. The self-reported data showed higher arousal for spinal flexion subjects, consistent with the SCL. Therefore, the question here becomes how much of the SCL difference across the two postures seen in Figure 2 is due to emotional arousal, how much is due to the posture manipulation alone, and how much to both.

It should be noted that most of the self-reported scales failed to show an effect of body posture. The exceptions are the positivity and negativity scales, which indicated a slight difference between the two stances in terms of the polarization of the emotional response. Again, we saw that the difference between positive and negative messages was larger for those in a neutral spine, suggesting a more congruent emotional response. Nevertheless, the fact that we see significant posture effect on our physiological but not in our experiential system indicates that the disadvantage of holding the flexed spine is beyond the sore neck and far greater than what people might expect. Our study shows that the flexed spine position when using media hampers our learning from media and attenuates our body experiences, especially when we need media to entertain ourselves.

This research shares the embodied cognition framework with a lot of other research in social psychology. One closely related area is power pose research. As we mentioned earlier, the robustness of power posing and the appropriate hypothesis have been under debate for more than one decade (Cesario et al., 2017; Loncar, 2021). Later research failed to replicate the original research (Carney et al., 2010) leading to many critiques about the validity and credibility of this literature. Most research seems to suggest that the power pose could affect feelings of power, but its effect on the body's hormone level remains in question. While our research does not directly draw from the power pose literature, our results revealed an interesting finding opposite to that line of research. Specifically, this study shows that the impact of spinal posture on information processing is on unconscious physiological processes, not on the experiential level.

This study has its limitations. First, participants were not randomly assigned to the spine posture condition due to the difficulty of lab arrangement and therefore data collected for the spinal flexion condition was earlier than for the neutral spine condition. When possible, future studies may try to replicate this study by using two labs with one for each viewing condition for random assignment, which would require two identical sets of lab equipment and settings. Second, the stimulus content in this experiment is limited to two topics. Although data in this study revealed no topic-specific results, a replication study with more varied stimuli, particularly stimuli likely to be viewed on mobile devices while the neck is in flexion (Reeves et al., 2021), would generalize the results to wider contexts. In particular, videos for education purposes requiring more cognitive resources may enlarge the posture effect, as the neutral spine posture may lead to deeper processing than they do for the current PSAs, whereas the spinal flexion posture keeps viewers in a message disengagement mode. Third, this study employed young college students as participants which may shrink the posture effect on information processing because most of them do not suffer from neck pain. Future studies should test the posture effect on people with mild or severe chronic neck pain, or older people whose job requires long sitting times. A larger posture effect may be observed from those groups than the results presented here. Finally, future research may employ smart phones rather than tablets to see if screen size differences and viewing distance would alter the findings.

Overall, this study supports the theoretical notion that processing of media messages is not just a "in-your-head" cognitive activity, but a dynamic process that involves the body of the viewer. Practically, this study calls for people's attention to the body posture when using media. Holding a neutral spine posture benefits the mind's cognitive and emotional processing by increasing our attention to the media and maximizing the emotional experiences, which are key to learning and to message persuasion as a result of video viewing. For example, our results suggest that PSAs viewed with spinal flexion posture may be less persuasive than ones viewed with a neutral spine posture. For topics like safe driving and sexual health that are extremely relevant to college students, holding a neutral spine posture during those PSA viewing might be more effective for the purpose of persuasion. Future research should extend this research by examining the posture effect at attitudinal and behavioral levels. Lastly, it is worth noting that physiological measures were more sensitive to the manipulation of body posture than self-reported measures and might therefore be a more adequate tool for studying embodied media effects.

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ORCID iDs

Lucía Cores-Sarría https://orcid.org/0000-0002-6422-2775
Jingjing Han https://orcid.org/0000-0002-1068-8887
Robert F. Potter https://orcid.org/0000-0002-9294-3940

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Author Biographies

Lucía Cores-Sarría is a postdoctoral fellow at the Digital Democracy Center at University of Southern Denmark. Her research looks at how the perceptual features of moving images shape the cognitive and emotional responses of viewers. Her theoretical perspectives on media are informed by ecological psychology and an embodied approach to cognition.

Jingjing Han is an Assistant Professor of Communication in the School of Journalism at Fudan University. Her research looks at how the human brain and body process audiovisual information cognitively and emotionally. Her research is guided by the complex dynamic systems theory, and includes nonlinear dynamical analysis and computational modeling techniques.

Jessica G. Myrick is a Professor of Communications at Penn State University. Her research examines the interplay of emotion and cognition in shaping audience media use and effects, particularly messages about health, science, and the environment. Her research also examines processes of audience involvement with public figures and their implications for individual and public health.

Robert F. Potter is a Professor of Communication Science and Director of Graduate Studies in the Media School at Indiana University Bloomington. His research focuses on increasing the understanding of how aspects of media impact attention and emotion. His primary interests focus on auditory variables.