

Changes in physiological states by swearing in adolescents: a pilot study using heart rate variability and EEG

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Abstract

We investigated the influence of swearing on physiological systems in high school students by measuring heart rate variability (HRV) and electroencephalography (EEG). In total, 15 male students of the first grade in high school were divided into two groups based on their frequency of swearing: highly frequent swearing (HFS, $n = 8$) and low frequency swearing (LFS, $n = 7$). They were listened to under three conditions of conversation: every-day conversation without swearing (EC), a conversation consisting of light swearing (LS), and conversation consisting of severe swearing (SS). The results of the HRV analysis were as follows: the HRV of the two groups showed a significant difference in SS conditions in both LF and HF. The LF norm was higher in LFS (HFS: 47.6, LFS: 63.3) and the HF norm was higher in HFS (HFS: 52.4, LFS: 36.7). The LF/HF ratio in the SS condition was significantly different between the groups. (HFS: 1.0, LFS:1.9). The results of the spectrum analysis of the EEG were significantly different in the alpha wave of Fp2 in the EC condition between HFS and LFS, although no significant difference was found in other brain waves under LS and SS conditions. In the severe swearing condition, the LFS group showed higher activity of the sympathetic system and the HFS group showed a higher parasympathetic response. This indicates that students using highly frequent swearing become physiologically desensitized to the severe swearing condition. Also, on the basis of the neuroanatomical structures associated with cortico-subcortical inhibition, this desensitization may suggest a negative influence on cognition, emotion regulation, or even psychological health.

Key words: Heart rate variability, EEG, Swearing, Taboo words, Sympathetic system, Parasympathetic system, Central autonomic network, Cortico-subcortical inhibition, Self-regulation

Introduction

Swearing is the use of profane or obscene language. It is used to show desecration or debasement of someone or something, or show strong or intense emotion [1]. Recently, South Korean adolescents have overused swearing: 73% of adolescents from 5th grade of elementary school to 3rd grade of high school replied that they swear everyday [2]. According to a public survey in 2010, the use of swearing that does harm to others is a severe problem in South Korean adolescents [3]. Swearing is used without consideration among them and not using swearing even makes them feel less familiar sometimes. Most adolescents replied that they use swearing habitually and some of them have no idea what the swear words really mean [3].

The psychological impact of swearing cannot be ignorable from the perspective of social relations. Swearing can induce aggression in adolescents. According to results of a public survey, after hearing swear words, most adolescents reported increased aggression, in linguistic, behavioral, or passive form [3]. Also, swearing in daily life might have negative interpersonal consequences [4], and it can undermine psychological adjustment and affect emotional support in coping processes [5].

From the perspective of neuropsychology, severe aphasia, adult left hemispherectomy, Gilles de la Tourette syndrome, and other neurological disorders, such as traumatic brain injury, encephalitis, and dementia have been reported to increase the use of swear words [6]. These reports suggest that swearing is associated with pathophysiology in the human brain.

Although there are few reported investigations on the neurophysiologic effects of swearing, recently a study showed that autonomic responses to swear words were larger than those to euphemisms and neutral stimuli, when measured by electrodermal activity [7]. Also, Stephens *et al.* noted that an accelerated heart rate following swearing is consistent with the idea that it may increase negative affect, such as aggression. When subjects were asked to swear when exposed to cold stimuli, swearing increased pain tolerance, increased heart rate, and decreased

perceived pain. The observed hypoalgesic effect may occur because swearing induces a fight-or-flight response and nullifies the link between fear of pain and pain perception [8]. Because severe swearing among teenagers has become a social problem in South Korea, in the present study, we examined the physiological impact of swearing especially on adolescents who use swearing frequently. To explore changes in the autonomous and central nervous systems by swearing, we measured heart rate variability (HRV) and electroencephalograph (EEG) in high school students exposed to several conditions of swearing. HRV is known as a measure of central-peripheral neural feedback and central nervous system (CNS)-autonomic nervous system (ANS) integration. Individual differences in HRV are linked to performance on tasks relevant to executive function and prefrontal cortical activity [9]. Also, EEG was measured in the prefrontal area, because the prefrontal cortex has been implicated in affective processes including emotional regulation, affective set-shifting, and extinction, all of which also rely heavily on inhibitory processes [9].

Methods

Participants

Fifteen male high school students (1st grade) participated in this study; they were divided into two groups. One group ($n = 8$) consists of students using highly frequent swearing (HFS, > 100 times per day) and the other ($n = 7$) students used low frequency swearing (LFS, < 10 times a day). The frequency of swearing was measured by survey.

All subjects provided informed consent prior to participation in the study. This study was approved by The Catholic University of Korea Institutional Review Board.

Materials

Three conversation conditions were digitally recorded beforehand and were presented to each

group as follows: (1) every-day conversation conditions with no swearing (EC), (2) conversation conditions consisting of light swearing, expressing familiarity among friends (LS), and (3) conversation consisting of severe swearing, expressing hatred and insults (SS). The swear words were classified into five levels according to severity [3]. The LS used words from the level 1 severity swear words, and SS from level 5. We measured EEG (Fp1 and Fp2) and HRV during the presentation of the three different conversation conditions, using an ECG (Wise-8000, MooYoo Instruments, Seongnam, Korea). The spectral components of HRV, low frequency (LF) and high frequency (HF) were adopted as markers reflecting activity of the autonomous nervous system. Efferent parasympathetic activity is a major contributor to the HF component, and the interpretation of the LF component is considered as a marker of sympathetic modulation [10].

Results

The results of HRV analysis were as follows. LF norm: In the EC condition, the HRVs of the two groups showed no difference (HFS: 62.6 ± 11.4 , LFS: 62.8 ± 7.9 , ns). In the LS condition, the HRV of the two groups showed no difference (HFS: 54.2 ± 14.3 , LFS: 61.2 ± 11.3 , ns). However, the HRV of the two groups showed a significant difference in the SS condition (HFS: 47.6 ± 11.4 , LFS: 63.3 ± 10.5 , $t(1,13) = -2.763$, $p = 0.016$). HF norm: In the EC condition, the HRV of the two groups showed no difference (HFS: 37.4 ± 11.4 , LFS: 37.2 ± 7.9 , ns). In the LS condition, the HRV of the two groups showed no difference (HFS: 45.8 ± 14.3 , LFS: 38.8 ± 11.3 , ns). However, the HRV of the two groups showed a significant difference in the SS condition (HFS: 52.4 ± 11.4 ; LFS: 36.7 ± 10.5 , $t(1,13) = 2.763$, $p = 0.016$). LF/HF ratio: In the EC condition, the HRV of the two groups showed no difference (HFS: 2.0 ± 1.2 , LFS: 1.8 ± 0.8 , ns). In the LS condition, the HRV of the two groups showed no difference (HFS: 1.6 ± 1.5 , LFSU: 1.8 ± 0.9 , ns). However, the HRV of two groups showed a significant difference in the SS condition (HFS:

1.0 ± 0.4 , LFS: 1.9 ± 0.7 , $t(1,13) = -2.976$, $p = 0.011$; Fig. 1 (A)).

The results of the EEG spectrum analysis showed a significant difference in the alpha wave of Fp2 in the EC condition (HFS: $34.7 \pm 2.9\%$; LFS: $31.9 \pm 2.0\%$, $t(1,13) = 2.167$, $p = 0.049$) but no difference in any other brain wave in LS and SS conditions between HFS and LFS (Fig. 1 (B)).

Discussion

In the severe swearing condition, the LFS group showed a higher LF/HF ratio than the HFS group, indicating higher activation of the sympathetic system associated with hearing severe swearing. In the same condition, the HFS group showed a significantly higher HF norm than the LFS group, reflecting higher activity of the parasympathetic system associated with vegetative and restorative functions. Normally, the expected response to swearing is fight-or-flight response, with increased sympathetic tone [8]. However, students who use swearing more frequently lacked this response and this could be explained in that they are desensitized to emotional stimuli.

Stephens and Atkins demonstrated a pain-lesseing effect of swearing [8]. An additional variable, the influence of daily swearing frequency on the pain-lesseing effect of swearing was assessed. The more often participants used swearing in their daily life, the shorter time they were able to hold their hand in cold water while repeating a swear word [11]. This study is similar to ours in that it is an example of a decreased physiological response to swear words as the frequency of swearing increases. Compared with this study, we used HRV as a physiological marker to assess activity in the autonomic nervous system, and HRV results differed significantly depending on the frequency of swearing by the participants. The more frequently the students used swear words, the less sympathetic response to swear words the students had.

HRV is a possibly useful marker of neurovisceral integration, and also known to be associated with various regions of the central nervous system [12]. HRV has been associated with a diverse range of processes, including affective and attentional regulation [13]. The functional network called the central autonomic network (CAN), including the anterior cingulate, insular, and ventromedial prefrontal cortices, the amygdala, and the hypothalamus, is known to integrate intrinsic and extrinsic information and to coordinate autonomic, endocrine, and behavioral responses to environmental changes [14].

The CAN can be divided into sympathetic and parasympathetic regions, and brain areas associated with sympathetic regulation mainly involved the prefrontal, anterior cingulate, and other regions of the brain [15]. Also, anterior cingulate cortex is a well-known hub for self-regulation, such as attention, action, and emotional responding [16-17]. Sympathetic regions of the CAN are also predominant in cognitive tasks and emotional processing, especially in the evaluation of aversive stimuli [18].

In the present study, the frequently swearing students lacked the expected sympathetic tone towards emotionally negative stimuli. From this result, we suggest that frequent swearing may disrupt physiological responses mediated via CAN, especially sympathetic regulation mediated by the anterior cingulate cortex and other regions of the brain. Based on neuroanatomical structures and functions, we consider that autonomic dysregulation of emotional stress is associated with not only abnormal physiological functioning but also abnormal self-regulation, cognition, and emotional processing.

Many studies have been conducted to investigate the autonomic responses to aversive stimuli, suggesting CAN hypofunction has a major role in regulating emotional responses [19-21]. In particular, there are studies on autonomic reactivity in various pediatric psychopathologies. It is well established that externalizing behavior problems are associated with reduced sympathetic activity and altered parasympathetic responses during emotion-based

tasks and rewards [22-26]. Children with attention-deficit/hyperactivity disorder (ADHD) displayed increased parasympathetic activity when exposed to emotional tasks [27]. Conductive disorder children showed low levels of electrodermal responses to aversive stimuli [23]. These results are also supported by neuroimaging in that particular CAN regions were found to be abnormal in functional brain magnetic resonance imaging (fMRI) [28].

Although most of these studies used electrodermal activity, they have similar results to the present study in terms of hyporesponsiveness to ‘emotionally charged’ stress. There is not enough evidence to conclude that frequently swearing adolescents may have risks of actual psychopathological problems. However, there is a common feature that they have autonomic dysregulation to emotional stimuli, meaning disinhibition of cortico-subcortical inhibition.

Cortico-subcortical inhibition related to self-regulation starts developing very early in life, and keeps developing throughout childhood and adolescence [16]. Whether swearing has a negative effect on this development of self-regulatory systems, or imbalance of cortical inhibition makes adolescents use swearing, frequent swearing in childhood and adolescents appears to be not very desirable for development of the brain.

To prove an association between swearing and cognitive function, emotion regulation, or any of the mentioned psychopathologies, neuropsychological tests, such as frontal lobe function tests, or questionnaires may provide clues. Also, longitudinal studies to follow these students and observe their social skills, or individual achievements would be helpful.

There were significant differences in HRV between HFS and LFS only when the students were exposed to severe swearing conditions. Thus, a question may be raised as to whether these results really reflect autonomic imbalance or self-regulatory executive functions, or even psychological problems in every-day life. However, as highly frequent swearing students may be exposed to severe swearing conditions [3], desensitization to severe swearing may be generalized to every-day life.

The only significant result in the EEG measurements was a slightly increased alpha activity of the HFS group in the EC condition. Alpha waves are known to originate predominantly from the occipital lobe during relaxation with closed eyes [29]. As alpha waves are thought to represent a resting state, this result could be interpreted as that more frequently swearing students were more relaxed in non-swearing conditions than less-swearing students. This might be due to an advantageous effect of swearing: that is, it is cathartic or an acceptable substitute for physical aggression [4]. We might consider that frequently swearing students express their aggression more readily so they could be more relaxed in every-day conversations. However, there are not enough grounds to conclude that swearing has a relaxing effect in neutral conditions. One study examined cortical responses to verbal abuse using ERP components (P100 and N400). Swear words elicited different patterns of cortical activation to neutral or positive emotional words [30]. Rather than EEG, ERP is considered to be a better tool for measuring brain activity in the swearing stimuli-provided environment.

This study had several limitations. First, the sample size was quite small and it was limited to only male students in the first grade of a high school. Thus, the results should not be generalized without further studies. However, the observed effects were statistically reliable. Second, the machine used to measure EEG had only two channels (Fp1 and Fp2), which is much simpler than a conventional EEG machine. As EEG was measured only in prefrontal cortex in this study, the result might not reflect brain waves in other brain regions.

Our study suggested desensitization of physiological response to severe swearing among adolescents who use swear words frequently. To our knowledge, this is the first report about the autonomic influence of swearing, stratified by severity and frequency. Future studies are needed with larger sample sizes, participants of various ages within adolescents, and both genders. As we suggested, swearing may be related with pathophysiology of the brain structure, so brain fMRI in swearing or neutral conditions, stratified by frequency of swearing, would be

helpful to explore which region(s) of the brain is involved in swearing and the desensitization to swear words. Prospective studies may show correlations of swearing and performance tasks, cognitive function, interpersonal relationships, and psychological problems.

Conclusion

In the severe swearing conditions, the LFS group showed higher sympathetic system activity. Under the same conditions, the HFS group showed higher parasympathetic system activity. These results indicate that students who are swearing frequently may become physiologically desensitized to severe swearing, and this may lead to a negative influence on their cognitive and executive function or even psychological health.

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Conflicts of interest

There are no conflicts of interest.

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Figure legend

Figure 1. Heart rate variability (Norm LF, Norm HF, LF/HF ratio) and alpha waves of Fp2 in the HFS and LFS groups.

