

# Relationship Analysis of Speech Communication between Salivary Cortisol Levels and Personal Characteristics Using the Smartphone Linked Stress Measurement (SLSM)

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Received: 18 July, 2016 / Accepted: 23 September, 2016 / Published online: 04 January, 2017  
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**Abstract** Salivary cortisol is frequently used as a biomarker of stress. However, no study has used salivary cortisol to evaluate stress levels related to personal characteristics with a paper-based lateral flow assay (LFA) strip and a smartphone holder, and a smartphone at the same time during simulated speech communication. In this paper, we investigated variations in levels of salivary cortisol, communication apprehension, and the effects of self-efficacy via the Smartphone Linked Stress Measurement (SLSM) that we have recently reported. Saliva samples were collected by 48 participants (30 male and 18 female) at three moments: immediately before public speaking (basal measurement), immediately after public speaking (speech measurement), and forty minutes after taking a rest (relaxed measurement). Results from the questionnaire showed that salivary cortisol levels, communication apprehension, and self-efficacy were significantly correlated. Also, anxiety about speaking can raise their stress levels during their speeches, as reflected in their increased cortisol levels. Therefore, this study establishes the effects of self-efficacy on communication apprehension and salivary cortisol.

**Keywords:** Speech communication, Salivary cortisol, Lateral flow assay, Smartphone, Stress measurement

## Introduction

Saliva has long been known to be an easily accessible biological fluid, and salivary cortisol is frequently used as a biomarker of stress<sup>1</sup>. Salivary cortisol is partly dissociated from cortisol in the blood<sup>2</sup>. Therefore, a high correlation holds between salivary and blood cortisol. As salivary cortisol can be easily collected over a long time period, the real-time detection and continuous monitoring of cortisol can be done with human saliva.

Performance tasks accompanied by stress have been found regarding high cortisol levels in human body<sup>3</sup>. Changes in cortisol concentration are known to mark reaction to stressors. Specifically, studies have found that not only raised cortisol levels during an evaluative speech task<sup>4,5</sup> but also that public speaking is the most-feared communication situation<sup>6</sup>. During laboratory tasks for public speaking, the level of cortisol increases<sup>7</sup> and the cortisol responses were most apparent among people who had suppression and reappraisal traits<sup>5</sup>.

However, the correlation between the input of stressors and the cortisol level is inconsistent and depends on the type of tasks or stressor domains. Some studies support a positive relationship<sup>8,9</sup> while others report a significantly consistent relationship between perceived stressors such as anxiety and cortisol activity<sup>10,11</sup>. Therefore, individuals' traits, such as communication apprehension and self-efficacy, should be considered

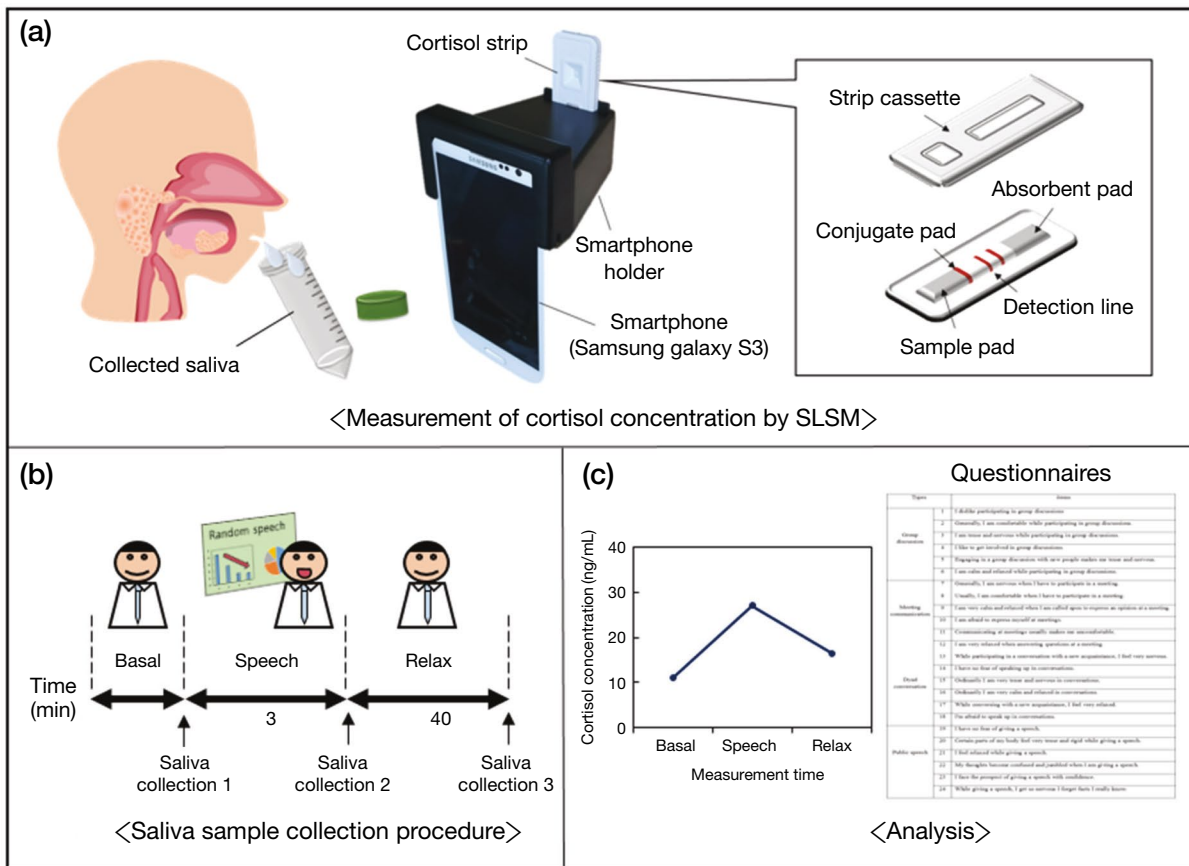
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**Figure 1.** Salivary cortisol measurement protocol. (a) The configuration of the Smartphone Linked Stress Measurement (SLSM) used for the salivary cortisol level detection. The SLSM was composed to the cortisol strip, smartphone holder, and smartphone. Sample pad absorb saliva sample and reaction part conjugation pad contain antibody conjugated gold nanoparticle which capture antigen in saliva. On the nitrocellulose membrane immobilized antibody capture antigen combined with gold nanoparticle. Absorbent pad makes sample go through nitrocellulose membrane. The smartphone holder was designed using Solidworks 2010 (Solidworks Corporation, Concord, MA, USA). (b) Timetable of the experimental procedure. Salivary samples were taken three times (basal time, speech time, and relaxed time). (c) Analysis method using questionnaires and cortisol concentration.

along with an objective measuring method to obtain consistent and detailed data<sup>12</sup>. Till date, no study has derived a level of stress related to personal characteristics from salivary cortisol during simulated speech communication.

In our previous research<sup>13</sup>, assuming that an instant salivary cortisol assessment can be an objective evaluation method for various types of researches in the fields of social science, we developed the system of measuring a concentration of salivary cortisol using a lateral flow assay (LFA) strip, a smartphone holder, and a smartphone, named as the Smartphone Linked Stress Measurement (SLSM) as shown in Figure 1a.

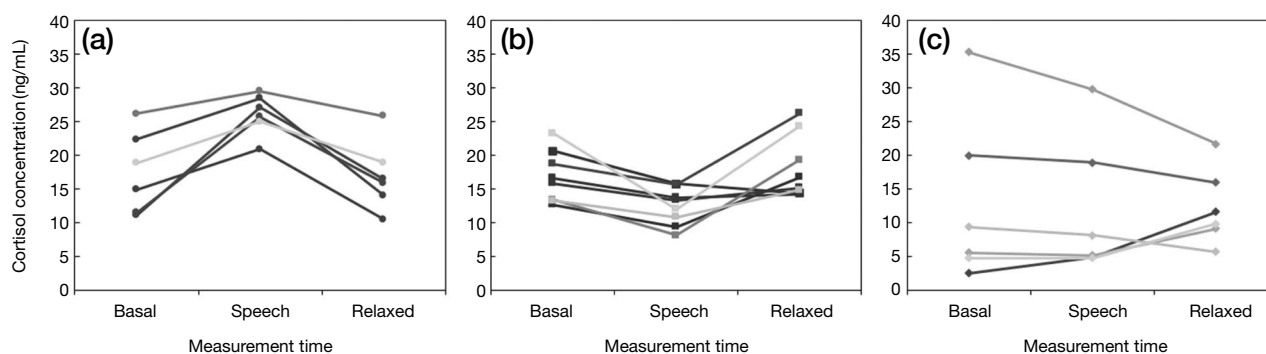
In this paper, our SLSM was applied to measure a psychological stress level regarding the pressure of public speaking and simultaneously self-efficacy and communication apprehension were measured by the

self-efficacy scale and personal report of communication apprehension (PRCA-24).

## Definition

### Communication Apprehension

Communication apprehension has been one of the most studied factors in interpersonal communications. Communication apprehension is defined as “individual’s level of fear or anxiety associated with either real or anticipated communication with another person or persons”. It relates to avoiding social interactions<sup>14</sup>. Communication apprehension evokes individuals’ negative feelings about communication and brings about unexpected negative results<sup>15</sup>. Regardless of cultural back-



**Figure 2.** Salivary cortisol responses to speech communication stress in undergraduate students at each time point (values were adjusted for basal, speech, and relaxed times,  $n = 20$ ). (a) Group A (pyramid type,  $n = 6$ ); (b) Group B (inverted pyramid type,  $n = 8$ ); (c) Group C (remainder type,  $n = 6$ ).

ground, people with strong communication apprehension tend to have a weak desire to communicate and demonstrate low confidence in their communication skills<sup>16,17</sup>. People with the higher levels of communication apprehension are most likely to be unsuccessful in their interpersonal interactions<sup>12</sup>. Therefore, communication apprehension will be a factor that raises the level of stress in public speaking.

### Self-efficacy

Self-efficacy is one's judgment of his or her capabilities to organize and execute courses of action required to attain designated types of performance<sup>18</sup>. Bandura<sup>19</sup> argue that self-efficacy determines how people feel, think, and motivate their will and behaviors. Therefore, people with the higher levels of self-efficacy consider difficult tasks as challenges to be mastered rather than as threats to be avoided. He also noted that a strong sense of self-efficacy enhances individuals' sense of accomplishment and well-being. In this sense, those with higher levels of self-efficacy will have better motivation and self-confidence during public speaking.

## Results and Discussion

### Cortisol Levels at Each Time Point

Measurements of cortisol levels were taken during speech communication. The time-course changes in salivary cortisol from the three groups are shown in Figure 1b. The three groups showed cortisol stress reactivity while controlling for basal (right before the public speech), speech (right after the public speech) and relaxed (40 minute after taking a rest). For the purpose of assessing the psychological impacts of the public speech were analyzed using the linear mixed

model as a pyramid, an inverted pyramid, and a remainder type. The linear mixed model for cortisol concentration in the subjects showed a significant main effect of time (Figure 2a-c).

The post hoc test for time indicated that the cortisol level of group A (pyramid type,  $n = 6$ ) right before speaking was higher than that immediately after speaking and 40 minutes after taking a rest (Figure 2a).

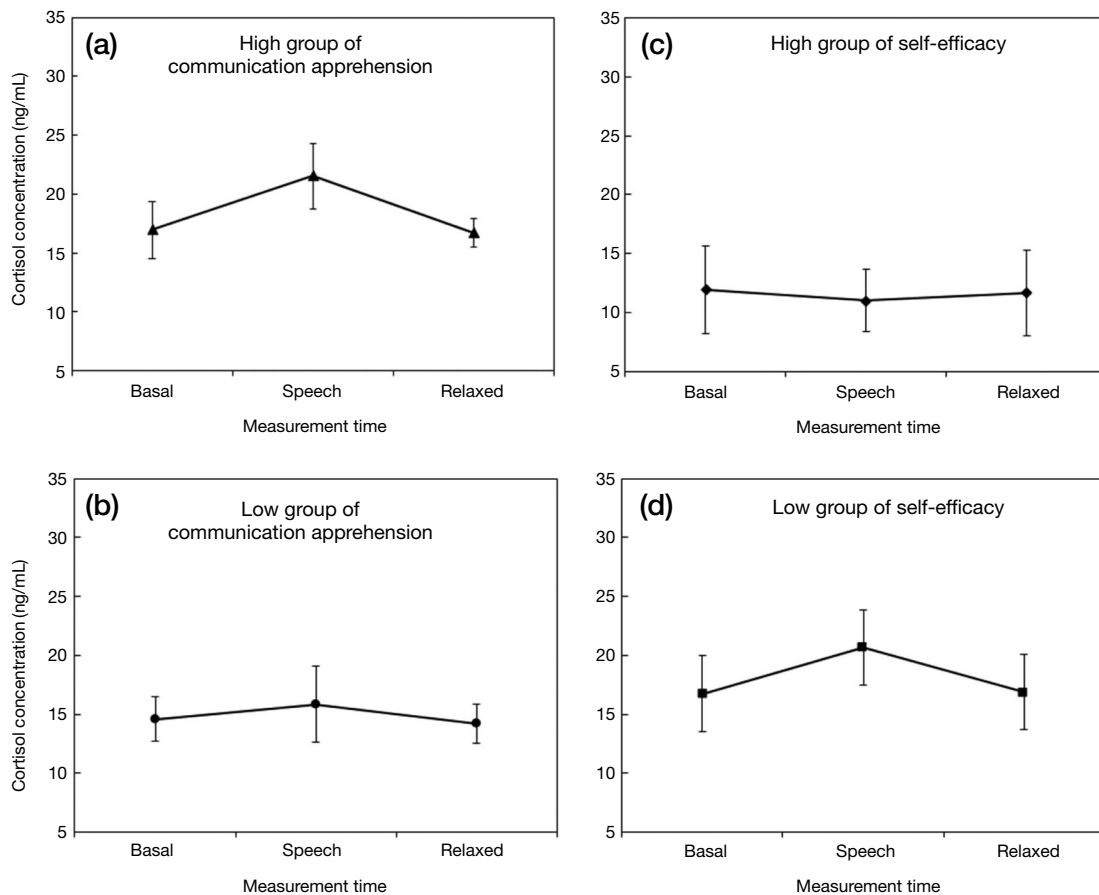
The post hoc test for time indicated that the cortisol concentrations for group B (inverted pyramid type,  $n = 8$ ) were higher immediately before speaking and 40 minutes after resting than immediately after speaking (Figure 2b).

Group C (remainder type,  $n = 6$ ) interactions indicated that cortisol levels right before speaking were higher than those right after speaking and 40 minutes after taking a rest, and cortisol concentrations right after speaking were higher than those 40 minutes after taking a rest. On the other hand, some subjects' cortisol concentrations were higher 40 minutes after taking a rest than right before and after speaking (Figure 2c).

The focus of this study was to explore the effect of cortisol level during the speech communication. Notably, this study investigated cortisol levels at three points basal, speech, and relax. The cortisol levels were elevated during the speech or relax, indicating that the cortisol levels increased in the significant main effect of time. As a results, we supposed that the cortisol levels of three group (pyramid type, inverted pyramid type, remainder type) were affected the self-efficacy and communication apprehension.

### Discriminating between Self-efficacy and Communication Apprehension

Figure 3 shows salivary cortisol levels by level of both self-efficacy (SE, high SE (HSE) and low SE (LSE)



**Figure 3.** Comparison of salivary cortisol activity during the basal, speech, and relaxed times (a) HCA group (n = 7), (b) LCA group (n = 6), (c) HSE group (n = 10), and (d) LSE group (n = 6). The data show the mean and standard deviations for each group.

groups) and communication apprehension (CA, high CA (HCA) and low CA (LCA) groups), respectively. Statistical calculations were performed with SPSS statistics.

Salivary cortisol levels for the remainder type for communication apprehension increased from 11.76% (HCA, 2/17) to 26.67% (LCA, 4/15). Levels for the pyramid and inverted pyramid types decreased from 35.29% (HCA, 6/17) to 33.33% (LCA, 5/15) and from 52.94% (HCA, 9/17) to 40.00% (LCA, 6/15), respectively. For the self-efficacy groups, levels for the remainder type decreased from 26.31% (HSE, 5/19) to 15.38% (LSE, 2/13). Levels for the pyramid type (from 31.58% (HSE, 6/19) to 38.46% (LSE, 5/13)) and inverted pyramid type (from 42.21% (HSE, 8/19) to 46.15% (LSE, 6/13)) increased (data not shown).

The time-course changes in salivary cortisol of the four groups are shown in Figure 3a-3d. The data show the mean and standard deviations for each group. The cortisol mean levels of the HCA group at basal, speech,

and relaxed times were  $16.97 \pm 2.42$ ,  $21.52 \pm 2.74$ , and  $16.71 \pm 1.23$  (Figure 3a). The mean of the HCA group during speech was significantly higher than that for the basal and relaxed times. However, the means of the LCA group at the three times were  $14.57 \pm 1.88$ ,  $15.85 \pm 3.25$ , and  $14.21 \pm 1.65$ , respectively. The LCA group was virtually uninfluenced by the experimental procedure (Figure 3b).

The mean salivary cortisol levels for the HSE group were  $11.96 \pm 3.73$ ,  $11.00 \pm 2.66$ , and  $11.63 \pm 3.63$ , showing no significant difference between the basal, speeches, and relaxed times (Figure 3c). In contrast, the mean levels for the LSE group were  $16.75 \pm 3.20$ ,  $20.64 \pm 3.20$ , and  $16.86 \pm 3.18$ , respectively. The cortisol level for the LSE group at speech time tended to be higher than during the basal and relaxed times (Figure 3d). As a result, the salivary cortisol levels of all subjects significantly correlated with the questionnaire findings (Table 1).

This study demonstrated that human cortisol levels

**Table 1.** The relationship between communication apprehension and self-efficacy.

Groups		Cortisol concentration
Communication apprehension (CA)	High	↑
	Low	↓
Self-efficacy (SE)	High	↓
	Low	↑

obtained from saliva can be an indicator of stress levels. Changes in cortisol levels showed distinct patterns over the course of the public speaking event; these patterns corresponded to individual CA and SE traits.

Theoretically, measuring cortisol levels can verify the findings of previous studies and yield consistent information on psychological traits and reactions. In both the HCA and LSE groups, variations in cortisol level showed similar patterns: The levels increased to their highest point immediately after speaking, then decreased after forty minutes of public speech. Levels were lowest right before public speech. These cortisol level patterns reflected individuals' growing psychological anxiety while speaking. As noted in other studies, communication apprehension is associated with introverted neurotic responses<sup>20</sup> and thus with increased anxiety during the public speech. These findings are reflected in the cortisol level graphs.

Those with lower self-efficacy also showed the highest cortisol levels right after speaking. People with decreased self-efficacy tend to believe they cannot successfully overcome challenges<sup>21</sup>. Moreover, self-efficacy has been found to be related to effective communication skills<sup>22</sup>. It is possible that individuals with lower self-efficacy might be aware of their poor communication skills and thus worry about the quality of their speech. Therefore, anxiety about speaking can raise their stress levels during their speeches, as reflected in their increased cortisol levels.

## Conclusions

Salivary cortisol is frequently used as a detection biomarker of stress level. However, no study has used salivary cortisol to evaluate stress levels related to personal characteristics such as self-efficacy and communication apprehension.

From a practical perspective, taking cortisol levels from human saliva was found to be an effective method for obtaining consistent results. Instant and unobtrusive measurements have been recommended for

assessing individuals' psychological reactions more precisely to yield correct quantified outcomes<sup>23</sup>; A previous study has reported an association of salivary cortisol with stress<sup>24,25</sup>. Also, we developed the cortisol detection system using the paper-based LFA strip and the smartphone holder and the smartphone, named as the SLSM.

In this works, this study confirms the effects of self-efficacy on communication apprehension through salivary cortisol measurements using the SLSM<sup>13</sup>. Results from the questionnaire showed that salivary cortisol levels, communication apprehension, and self-efficacy were significantly correlated.

In addition to cortisol detection technology, a relevant future trend the development of smart watches or patch-type wearable sensors. Further studies will focus on helping to develop easy-to-use ways to detect the level of stress related to personal characteristics. This will have enormous potential for various applications, such as clinical mobile diagnostics, psychological health, burnout, academic stress, and treatments for other conditions.

## Materials and Methods

### Participants

The participants were 48 undergraduate students in a speech communication class. The 30 male and 18 female participants were on average 22.2 years old (SD = 1.69, range 19~26). All subjects were healthy and drug-free, and they were tested individually from noon to 3 p.m. to avoid the contamination of cortisol results due to lowered responsiveness of the adrenal cortex in the early morning hours. The subjects did not eat anything three hours before the test to avoid the effects of meal-related cortisol secretion.

### Saliva Samples

The experiment was conducted on the day of the final test of the speech communication class. Before the final test, the testing process and the scoring criterion were explained to the class. Proper construction of speech content, an exact length of speech, and correct pronunciation and grammar were significant factors for a good grade. On day of the final test, the students arrived in the classroom at their respective designated times. Each student was given a random theme on which to present a three-minute public speech, and was seated in front of a camera with a recording tape installed. Each student's saliva sample was taken three times, basal (right before speaking), speech (right after

speaking), and relaxed (forty minute after speaking), to check the baseline saliva level (Figure 1a, b). The collected samples were frozen at  $-20^{\circ}\text{C}$  and stored prior to analysis using the SLSM<sup>14</sup>. This study was approved by the Institutional Review Board (IRB) of Yonsei University, and all participants gave their informed consent.

### Personality Measurements

Self-efficacy and communication apprehension were

measured. The students who completed the third saliva collection filled out the questionnaires. To measure self-efficacy, the generalized self-efficacy scale<sup>26</sup> was used; this scale comprised ten items. Communication apprehension was measured by the PRCA-24, which is the most widely used scale of this type. The PRCA-24 has four dimensions (group speech, meeting speech, dyad (interpersonal) speech, and public speech), and each dimension is composed of six items.

### Self-efficacy scale

	Items
1	I can always manage to solve difficult problems if I try hard enough.
2	If someone opposes me, I can find the means and ways to get what I want.
3	It is easy for me to stick to my aims and accomplish my goals.
4	I am confident that I could deal efficiently with unexpected events.
5	Thanks to my resourcefulness, I know how to handle unforeseen situations.
6	I can solve most problems if I invest the necessary effort.
7	I can remain calm when facing difficulties because I can rely on my coping abilities.
8	When I am confronted with a problem, I can usually find several solutions.
9	If I am in trouble, I can usually think of a solution.
10	I can usually handle whatever comes my way.

### PRCA-24

Types	Items
Group discussion	1 I dislike participating in group discussions
	2 Generally, I am comfortable while participating in group discussions.
	3 I am tense and nervous while participating in group discussions.
Group discussion	4 I like to get involved in group discussions.
	5 Engaging in a group discussion with new people makes me tense and nervous.
	6 I am calm and relaxed while participating in group discussions.
Meeting communication	7 Generally, I am nervous when I have to participate in a meeting.
	8 Usually, I am comfortable when I have to participate in a meeting.
	9 I am very calm and relaxed when I am called upon to express an opinion at a meeting.
	10 I am afraid to express myself at meetings.
	11 Communicating at meetings usually makes me uncomfortable.
Dyad conversation	12 I am very relaxed when answering questions at a meeting.
	13 While participating in a conversation with a new acquaintance, I feel very nervous.
	14 I have no fear of speaking up in conversations.
	15 Ordinarily I am very tense and nervous in conversations.
	16 Ordinarily I am very calm and relaxed in conversations.
	17 While conversing with a new acquaintance, I feel very relaxed.
Public speech	18 I'm afraid to speak up in conversations.
	19 I have no fear of giving a speech.
	20 Certain parts of my body feel very tense and rigid while giving a speech.
	21 I feel relaxed while giving a speech.
	22 My thoughts become confused and jumbled when I am giving a speech.
	23 I face the prospect of giving a speech with confidence.
	24 While giving a speech, I get so nervous I forget facts I really know.

**Acknowledgements** This research was supported by a grant (14CTAP-C077516-01) from Infrastructure and transportation technology promotion research Program funded by Ministry of Land, Infrastructure, by the Industrial Fundamental Technology Development Program (10060195) funded by the Ministry of Trade, Industry & Energy (MOTIE) of Korea, and by the Bio & Medical Technology Development Program of the NRF funded by the Korean government, MSIP (2015M3A9D7067364).

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