Are Action-based Lies easier to detect than Speech-based Lies? : A Near-Infrared Spectroscopy Study

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Abstract

Previous research on the neural correlates of lying has revealed that the dorsolateral prefrontal cortex and the anterior cingulate cortex are significantly activated across several lying paradigms (Spence, 2008). However, more recently, Ding et al. (2012) have shown that specific types of lies (concealment vs. faking lies) have distinct neural correlates. Using Near-Infrared Spectroscopy, we examined whether action- vs. speech-based lies also have distinct neural correlates. Participants had three sessions: learning, recognition, and lying. In the learning session, participants produced a hand gesture or spoke aloud 20 sentences, respectively. In the recognition session, participants recognized whether they spoke or gestured a sentence via a key press. In the lying session, participants lied for 20 sentences and told the truth for another 20 sentences about whether they gestured or spoke via a key press. Our results revealed the right superior frontal gyrus was uniquely activated by action lies. This implies certain types of lies such as concealment, faking, and action lies activate unique regions of the brain.

Keywords: action, speech, lies

1. Introduction

In our daily lives we tell lies—we say things that did not occur. Recently, the brain activity of lying has become a topic of much interest (i.e., Abe et al., 2009; Baumgartner, Fischbacher, Feierabend, Lutz, & Fehr, 2009; Ganis, Rosenfeld, Meixner, Kievit, & Schendan, 2010; Sip et al., 2010; Spence, 2008). Spence (2008) found that in several different lying paradigms, the same regions of the brain are activated, e.g., the dorsolateral prefrontal cortex and the anterior cingulate cortex. Although this suggests that lying is connected to those brain regions, the neural correlates for lying may "depend very much on context" (Sip et al., 2010, p. 3626). For example, "concealment" and "faking" lies have previously been shown to activate distinct areas of the brain (Ding et al., 2012). In Ding et al.'s experiment, participants were presented with a series of names and then they were asked "Are you [name]?" The participants were further instructed to lie by denying their own name (conceal) or assuming a different name (faking). They found that the first type of lie, *concealment*, activated the right insular cortex and inferior frontal gyrus whereas the second type of lie, *faking*, activated the right superior frontal gyrus, the left calcarine, and the right caudate. In other words, if researchers are interested in certain types of lies, they may also need to investigate specific regions(s) of the brain.

Likewise, Saito, Palacios, Oi, Meng, Yamada, Itsukushima (2014), also investigated other types of lies: speech, action, and reading lies. Participants had three sessions: learning, recognition, and lying. In the learning session, participants produced a hand gesture or spoke aloud for visually presented sentences, on a monitor and also silently read other sentences. In the recognition session, participants recognized whether they spoke, gestured, read silently, or had never seen a sentence by pressing a key on a keypad. In the lying session, participants lied for sentences and told the truth for another sentences about whether they had seen or not seen a sentence by pressing a key. Saito et al. (2014) confirmed lying's activation was higher than truth's activation. However, they did not find regions of the brain with significant difference between Action and Speech. Perhaps, their lie task was too complex because it incorporated four sentence types (action, outer speech, inner speech, and new) and truth/lie commands. This complexity interfered with the participant's recall. That is, the ease of retrievability of events was low; it was difficult for the participants to remember what they did.

In the present study we examined the neural correlates only for speech and action lies in an effort to create a lying task with a high ease of retrievability of events.

We hypothesized that action- and speech-based lies would activate distinct areas of the brain. For example, the left middle and superior temporal regions was found to be active for speech (Price et al., 1994) while the inferior frontal gyrus was found to be active for action (Kuhn, Brass, & Gallinat, 2013). In Ding et al's experiment, lying activated several regions including the right superior frontal gyrus. Therefore, speech lies may be active in the temporal regions and action lies in the inferior frontal gyrus but both types of lies may be active in the superior frontal gyrus. If we are able to distinguish between these action- and speech-based lies, our experiment will add credit to the idea that the neural correlates of lying depend on "context." More specifically, we define "context" hereafter as ease of retrievability of events and type of lie.

Previous research using a similar paradigm as this one reported here has demonstrated that lying activation is higher than truth activation (Saito et al., 2014) and speech activation is higher than action activation (Palacios, Saito, Oi, Meng, Yamada, Itsukushima, 2014). Based on these previous works, we also predict the strength of activation as: Lie-Speech > Lie-Action > Truth-Speech > Truth-Action. However it is also possible that Lie-Action activation is higher than Lie-Speech activation because Action has an elaborated memory trace than Speech (Palacios et al., 2014; Saito et al., 2014). These two hypotheses diverge in factors to be stressed; the former emphasizes previous research's activation patterns only, while the latter emphasizes both previous research's activation patterns and memory strength.

2. Method

2.1. Participants

Nineteen Nagoya University students (15 males, 4 females, age: 18.3 ±0.6; all right-handed; all native Japanese) participated in the present experiment for course credit. This experiment consisted of three sessions: learning, recognition, and lying.

2.2. Materials and Procedure

The materials consisted of a total of 40 simple (Object-Particle-Verb) kana-only sentences presented on a monitor (e.g., ペン で かく; write with a pen). The primary particles in Japanese, DE (で) and WO (を), were used equally i.e., 20 WO and 20 DE sentences. All 40 sentences were used in the learning, recognition, and lying sessions. Sentences which participants were told to lie about were counterbalanced across participants. Two additional sentences were used for all practice trials (practice occurred before each session began).

2.2.1. Learning session.

In the learning session 40 sentences were presented on a monitor (LDT321V; Mitsubishi Elec., Japan). Half of the 20 sentences instructed the participant to "gesture" (using right-hand only) while the other 20 sentences instructed the participant to "speak aloud" the presented sentence. Participants were shown a monitor with one command (speak or act) and one sentence (e.g., "動作 ペン で かく). Action and speech sentences were randomly presented. Participants were presented the sentences for five seconds at a time via a monitor. After each sentence presentation, the screen turned blank for five seconds (resting period for acquiring neural data). The learning session began with two practice trials: one action and one speech.

2.2.2. Recognition session.

In the recognition session, participants were presented the same 40 sentences which were presented in the learning session. They were then asked to recall their learning-session performance and press the key “1” of a keypad (NT-18UBK, SANWA SUPPLY INC., Japan) if their performance was Speech or the key “2” if their performance was Action. Participants were presented one sentence at a time on a monitor until they made their choice or a maximum of 10 seconds had elapsed. Afterward the screen turned blank for five seconds (resting period for acquiring neural data). After the rest period, participants were also asked about the confidence of their decision using a 1-6 scale; 1 (No Confidence) to 6 (High Confidence). Participants were presented the sentence “(LOW) 1 ~ 6 (HIGH)” on a monitor until they pressed a number on a keypad or a maximum of five seconds had elapsed. Afterward the screen turned blank for five seconds (resting period for acquiring neural data). The recognition session began with two practice trials: one action and one speech sentence.

2.2.3. Lying session.

In the lying session, participants were presented the same 40 sentences which were presented in the learning and recognition session. In this session, participants were asked to lie or tell the truth about their performance (action or speech) in the previous sessions (learning and recognition). Participants were presented one command (lie or truth) and one sentence (e.g., 虚偽　ペン　で　かく) on a monitor. For the truth command, participants were instructed to give a truthful answer, i.e., if they spoke the presented sentence aloud in the learning session, then they were asked to press 1. Speech. For the lie command, participants were instructed to give a dishonest answer, i.e., if they spoke the presented sentence aloud in the learning session, then they were asked to press 2. Action. All answers were made with a keypad. Participants had a maximum of 10 seconds to make their choice. After each sentence presentation, the screen turned blank for five seconds (resting period for acquiring neural data). The lying session began with one practice truth trial sentence (speech) and two practice lie trial sentences (one speech and one action).

2.3. Evaluation Session.

After the experiment, participants completed a sentence evaluation task in which they were asked to rate each presented sentence in terms of comprehension, imagineability, frequency seen, frequency done, and criminality. This was used to assess the comparability of participants who participated in prior and subsequent experiments.

2.4. NIRS data acquisition.

A 95-channel NIRS unit operated at 780, 805 and 830 nm wavelengths (LABNIRS; Shimadzu, Japan) was used to measure the temporal changes in the concentration of oxygenated hemoglobin (Coxy-Hb), deoxygenated hemoglobin, and total hemoglobin. We focused on the changes in the Coxy-Hb since oxy-Hb is the most sensitive parameter of the regional cerebral blood flow (Hoshi et al., 2001; Strangman et al., 2002).

Each channel consisted of one emitter optode and one detector optode with a distance of 3 cm. 32 optode pairs covered the entire brain. The middle optode in the lowest line on the left side was located in the T3 position and the optode on the right side was on the T4 position (according to the international 10–20 system for electroencephalogram recording). The sampling rate for measurements was approximately 21 Hz. On the basis of a 3-dimensional probabilistic anatomical craniocerebral correlation, T3 and T4 were projected onto the left and right middle temporal gyri (Okamoto et al., 2004).

In this report we will only discuss NIRS data during the Lie session. The measurement periods in the Lie session consisted of a pre-task (1 s), the presentation of the fixation (1 s), Lie/Truth response (approximately 2 s), and rest (divided into 4 rest periods; 1×4 s = 4 s).

The raw data from fNIRS are all originally relative values and hence cannot be averaged directly across the participants or channels. To address this, raw data were converted to z-scores for analysis (Matsuda & Hiraki, 2006). The raw data of Coxy-Hb in Lie session in each trial and for each channel were converted into their corresponding z-scores. The z-scores were calculated using the mean value and the standard deviation of the changes in Coxy-Hb during the pre-task period. The z-scores were then averaged over the trials.

3. Results and Discussion

3.1. Behavioral Data.

The Recognition session consisted of two sentences types: Action and Speech. To determine whether the higher recognition rates for Action sentences than Speech sentences (Palacios et al., 2014; Saito et al., 2014) was replicated, we performed two tailed *t* test. Participants recognized Action sentences with 96.32% (*SD* = 4.36) accuracy and Speech sentences with 96.05% (*SD* = 4.27) accuracy; these results were not significantly different, *t* (18) = .170, *p* = .867. These results were not in line with (Palacios et al., 2014; Saito et al., 2014) which suggests the more simplified task in the present study raised the accuracy of participants' memory.

To examine the confidence of the participant's Performance (Speech, Action), we conducted a two tailed *t* test. Participants mean confidence levels for Action were 5.70 (*SD* = .28) and for Speech were 5.33 (*SD* = .72); Action confidence ratings was significantly higher than Speech confidence ratings, *t* (18) = 2.395, *p* = .028. These results are in line with Palacios et al., 2014 and Saito et al., 2014. The higher confidence for Action and the lower confidence for Speech may reflect a a more elaborative memory trace for Action than Speech.

The Lying session consisted of four sentences types: Action-Lie, Action-Truth, Speech-Lie, and Speech-Truth. The accuracy for Action-Lie was 93.68% (*SD* = 8.95), Action-Truth was 91.58% (*SD* = 8.98), Speech-Lie was 91.05% (*SD* = 7.37), Speech-Truth was 93.68% (*SD* = 9.55). We checked whether the accuracy (i.e., correctly chose the lie or the truth response key) of the four sentence types varied significantly by conducting a 2-way analysis of variance (ANOVA) with Veracity (Lie, Truth) and Performance (Speech, Action) as within factors. The results of the ANOVA revealed no significant main effects nor interaction; Veracity, $F(1, 18) = .022$, $p = .884$, $\eta^2_p = .001$, Performance, $F(1, 18) = .014$, $p = .907$, $\eta^2_p = .001$, and Veracity × Performance, $F(1, 18) = .885$, $p = .359$, $\eta^2_p = .047$. The high accuracy rates suggests that our lying task was simpler than Saito et al.'s (2014) lying task because our task showed higher rates of accuracy (for example, our task showed higher than 90% accuracy for Speech-Lie and Speech-Truth, whereas Saito et al. showed less than 50% accuracy for Speech-Lie and Speech-Truth).

We also measured the reaction times for the lying session. Figure 1 shows mean reaction time for the four response types. To determine whether Veracity, Performance or their interaction affected reaction time, we conducted a 2-way analysis of variance (ANOVA), with Veracity (2) and Performance (2) as within factors. The results of the ANOVA revealed significant main effect of Veracity, $F(1, 18) = 4.655$, $p = .045$, $\eta^2_p = .205$. In contrast, a main effect of Performance, $F(1, 18) = 3.145$, $p = .093$, $\eta^2_p = .149$, and an interaction Veracity × Performance were not significant, $F(1, 18) = .006$, $p = .937$, $\eta^2_p = .001$. The significantly lower reaction time for Truth than Lie indicates that telling a lie is more time-consuming and thus more difficult than telling than truth presumably because lying demands more cognitive resources than truth.

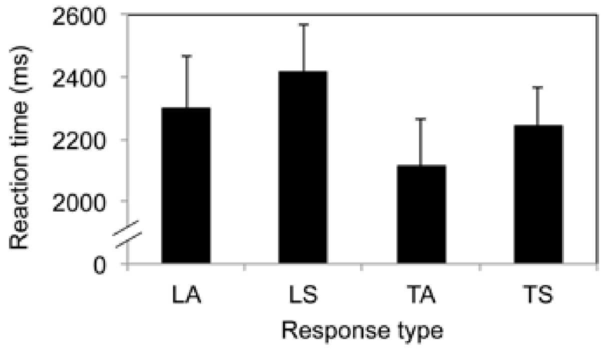

Figure 1. Mean reaction time for the four response types. LA: Lie-Action; LS-Lie-Speech; TA: True-Action; TS: True-Speech.

3.2. NIRS Data.

To determine which regions of the brain are related with Veracity (Truth, Lie) and/or Performance (Action, Speech) we conducted a 3-way ANOVA with Veracity (2), Performance (2) , and Period (5: Response (R), 1, 2, 3, 4; see Figure 1) as within factors. Violations of sphericity were corrected by the Greenhouse–Geisser correction. Error trials were excluded from subsequent analyses. In this article, we will only report our main finding: the significant 3-way interaction of Veracity × Performance × Period found in the left IFG (Channel 23), $F(4, 72) = .3.078$, $p = .044$, $\eta^2_p = .146$, and the right and left SFG (Channels 29, 74), Channel 29: $F(4, 72) = .3.693$, $p = .046$, $\eta^2_p = .170$; Channel 74: $F(4, 72) = 3.318$, $p = .015$, $\eta^2_p = .156$. The significant simple interaction of Veracity × Performance was found for Channel 74 in Period R, $F(1, 18) = 9.223$, $p = .007$, $\eta^2_p = .339$, and in Period 4, $F(1, 18) = 15.180$, $p = .001$, $\eta^2_p = .457$, but not for Channels 23 and 29. Figure 2 illustrates channel 74's neural activation. Simple main effect tests revealed (*ps* < .05) that Action-Lie demonstrated significantly higher activation than Action-Truth in Period R and 4, and in reverse, Speech-Truth is significantly higher than Speech-Lie in Period 4. Finally, Speech-Truth is significantly higher than Action-Truth in Period R and 4.

Other studies have also shown that lying activates the SFG more so than the truth (Davatzikos et al., 2005; Ding et al., 2012; Nunez et al., 2005). This may suggest that only particular types of lies activate the right SFG such as action lies. However the right SFG also showed Speech-Truth's activation higher than Speech-lie's activation. This suggests that the right SFG is affected differently based on the type of lie performance (action or speech in this case). That is, only the right SFG can be used to discriminate between speech-based and action-based lies.

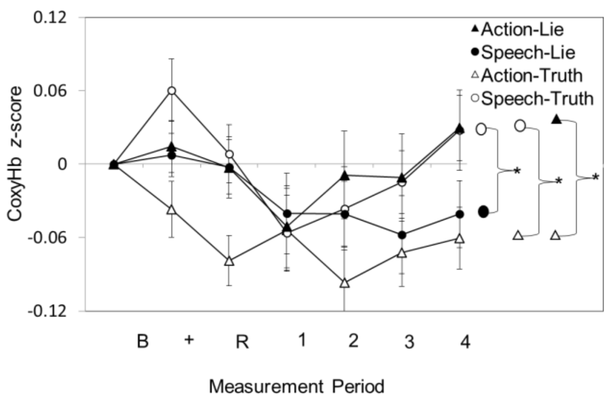

Figure 2. Average z-score of concentration changes in oxygenated hemoglobin (CoxyHb) during the seven measurement periods in the Lie session for channel 74. Measurement period B indicates the baseline, the + sign indicates fixation, R indicates the response period, 1-4 indicates the four rest seconds after the response. Error bars show standard error.

4. General Discussion

The main goal of this experiment was to determine whether action-based lies/truth and speech-based lies/truth have distinct neural correlates. We found that only channel 74, the right SFG, showed a unique activation for Action-based lies and Speech-based truth. We believe these results support the hypothesis that the neural correlates of lying depend on context, i.e., the interaction of: (1) ease of retrievability of events and (2) type of lie. We postulate that Action-Lie displayed more activation than Action-Truth due to the elaborative memory trace of action memories (supported by our confidence data; action confidence > speech confidence) combined with the comparatively higher-cognitive-load task of lying (supported by our reaction time data; lying task reaction time > truth task reaction time). We postulate that Speech-Truth displayed more activation than Speech-Lie due to rumination. That is, when participants performed Speech-Truth, they thought about their prior speech experience for a longer duration. We speculate that the right SFG reacts only to memories with more elaborative processes such as Action-Lie memories and the rumination of Speech-Truth memories.

In this experiment we have shown that action and speech-based memories affect distinctive areas of the brain which must be investigated to determine whether a participant is lying or telling the truth. If neural evidence is to be used in the courtroom (Giridharadas, 2008), such information regarding neural imaging data and context will prove invaluable.

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