Pertanika J. Sci. & Technol. 34 (5): 2675 - 2690 (2026)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

The Use of FSR-Based Plantar Pressure Patterns for Deception Detection

Gerelbat Batgerel and Chunki Kwon*

Department of Medical IT Engineering, Soonchunhyang University, 22 Soonchunhyang-ro, Sinchang-myeon, Asan-si, Chungcheongnam-do 31538, South Korea.

ABSTRACT

This study investigates plantar pressure patterns as a behavioural indicator of deception by analysing postural balance responses using force-sensitive resistor (FSR) sensors. A mock interrogation task was conducted in which subjects drew an apple on one of two sheets and responded to a question about whether they had drawn the apple, while plantar pressure was recorded. A brief perturbation was applied to induce a balance disturbance. Trials were classified as truthful or non-truthful based on the consistency between the subject's verbal responses and actual behaviour. Results showed that truthful trials exhibited stable balance and rapid recovery, whereas non-truthful trials demonstrated greater instability and delayed recovery, reflected in prolonged plantar pressure shifts. Importantly, consistent differences in recovery dynamics were observed from three additional participants, suggesting a potentially reproducible behavioural pattern. These findings indicate that deception-related cognitive and emotional processes may influence postural control. While this study represents a proof-of-concept feasibility investigation, it suggests that plantar pressure analysis may provide a non-invasive approach for detecting deception-related behavioural responses.

Keywords: 2D Matrix FSR sensors, deception detector, foot pressure pattern, involuntary postural reactions

INTRODUCTION

Deception detection plays a critical role in forensic investigations, legal proceedings, and security screening. Conventional approaches, particularly polygraph testing, infer deception indirectly by measuring physiological responses such as heart rate, respiration, and electrodermal activity, based on the assumption that deceptive responses are associated with increased psychological

ARTICLE INFO

Article history:
Received: 17 June 2026
Accepted: 06 August 2026
Published: 30 October 2026

DOI: https://doi.org/10.47836/pjst.34.5.06

Gerelbat47@gmail.com (Gerelbat Batgerel)
chunkikwon@sch.ac.kr (Chunki Kwon)
* Corresponding author

e-ISSN: 2231-8526

© Universiti Putra Malaysia Press

stress and autonomic nervous system activation (Grubin & Madsen, 2005; Krapohl & Shaw, 2015). However, these physiological signals require direct physical contact via electrodes and sensors, which can cause discomfort and increase psychological stress for examinees. They may be influenced by intentional countermeasures.

To overcome these problems in polygraph testing, recent studies have explored non-contact approaches, including vocal characteristics (Gallardo-Antolín & Montero, 2021; Kim, 2020) and facial expressions (Nam et al., 2021; Owayjan et al., 2012) as behavioural and cognitive indicators of deception. While promising, these approaches often exhibit variability across individuals due to differences in personality, cultural background, communication style, and expressive behaviour. Some individuals naturally exhibit minimal facial expressions or stable vocal patterns regardless of internal cognitive or emotional states, which can reduce the robustness of such approaches.

This study explores an alternative behavioural perspective by focusing on postural balance responses. The motivation for this work originates from a traditional observational test in which individuals appear to respond differently to unexpected perturbations depending on whether they are truthful or deceptive. Based on this observation, we hypothesise that deception may disrupt postural control and produce measurable changes in plantar pressure distribution (Batgerel & Kwon, 2026).

To test this hypothesis, plantar pressure patterns were measured using force-sensitive resistor (FSR) sensors embedded in insole devices. These sensors enable high-resolution monitoring of foot pressure distribution across the foot, providing quantitative information on postural balance and weight shifting.

The observation of plantar pressure patterns revealed a distinct difference between truthful and non-truthful trials when a brief external perturbation was applied. A truthful response was associated with minimal displacement and rapid balance recovery, whereas a deceptive response was associated with greater postural instability and a prolonged recovery time.

This balance disturbance was reflected in the plantar pressure distribution, with non-truthful trials showing larger and more sustained shifts in foot pressure than truthful trials. These observations suggest that postural balance may serve as a meaningful behavioural indicator of deception.

This balance disturbance was reflected in the plantar pressure distribution, with non-truthful trials exhibiting larger and more sustained shifts in foot pressure compared to truthful trials. These observations suggest that postural balance may serve as a meaningful behavioural indicator associated with deception. Furthermore, plantar pressure analysis using FSR sensors provides a non-invasive and quantitative method for detecting balance-related responses associated with deceptive behaviour.

Existing deception detection methods can generally be categorised into physiological signal-based approaches, such as polygraph testing, and non-contact approaches based

on facial expressions or speech analysis. While these methods have shown promising performances, they primarily rely on autonomic physiological responses or expressive behaviours. In contrast, the proposed method investigates deception from a different perspective by analysing perturbation-induced postural recovery through FSR-based plantar pressure measurements. By evaluating involuntary balance responses rather than physiological or expressive signals, this study introduces plantar pressure-based postural recovery dynamics as a novel behavioural indicator associated with deception. To the best of our knowledge, this is the first proof-of-concept study exploring perturbation-induced plantar pressure patterns for deception-related behavioural assessment.

This paper has been rewritten to improve the level of completion of the conference paper presented at the International Conference on Next-generation Convergence Technology Winter Conference 2026 (ICNCT2026) in Macau, China (Batgerel & Kwon, 2026).

LITERATURE REVIEW

Lie Detection and the Polygraph: A Historical Review

A historical overview of lie detection techniques is provided, with particular focus on the development, scientific foundation, and controversies surrounding polygraph testing. It aims to examine how polygraph technology has evolved and to evaluate its reliability and validity as a deception-detection tool (Grubin & Madsen, 2005).

Polygraph Practice as a Deception Detector

Fundamentals of Polygraph Practice explains lie detection by describing modern, evidence-based polygraph techniques that measure physiological responses associated with deception. It outlines validated methods for detecting lies through psychophysiological testing, data analysis, ethical considerations, and legal standards (Krapohl & Shaw, 2015).

Facial Expression as an Indicator of Deception Detector

Facial expressions are investigated as a non-contact deception-detection approach. In addition, the limitations of traditional contact-based lie detection methods are addressed. The results demonstrated the feasibility of detecting deception through facial expression dynamics. (Nam et al., 2021).

Real facial motion is analysed to derive the spatial and temporal patterns exhibited by the human face when attempting to lie. Facial micro-expressions are used to design and develop a real-time lie detection system (Owayjan et al., 2012).

Speech as an Indicator of Deception Detector

Speech is investigated as a non-contact method for deception detection. In addition, the limitations of traditional polygraph-based lie detection methods are addressed. Furthermore,

an important factor for a speech-based deception detection approach is introduced (Kim, 2020).

The development of an automatic deception detection system based on gaze and speech features. This research states that the dynamics of gaze and speech feature sequences can be an important indicator for LSTM network-based deception detection(Gallardo-Antolín & Montero, 2021).

METHODOLOGY

Experimental Setup

Plantar pressure patterns were measured using the Kitronyx MP2513 (2024) Insole Sensor Kit, which records pressure distribution at 30 Hz. This kit consists of a pair of insoles embedded with force-sensitive resistor (FSR) sensors. Each insole contains a 16x10 grid of FSR sensors (Figure 1a). For data collection using the MP2513 Insole sensor kit, the left and right insoles were positioned beneath the subject's feet (Figure 1b). Each insole independently captures a 16x10 plantar pressure matrix. When combined, the two insoles form a unified 16 × 20 sensing surface representing the plantar pressure distribution across both feet (Figure 1c). This configuration enabled real-time capture of plantar pressure distribution across the entire foot contact area. The device records plantar pressure pattern data at 30 frames per second (30Hz), providing dynamic, frame-by-frame measurements of the participant's balance adjustments throughout each 6-second trial.

The sampling rate used in this study is sufficient to capture overall balance displacement and postural recovery patterns following a perturbation. Considering that the observed recovery times ranged from approximately 0.4s to 1.7s, corresponding to 12-51 frames at 30 Hz, this temporal resolution was adequate for quantifying recovery dynamics. A rate of 30 Hz is also considered relatively high for real-time acquisition of a 16 × 10 FSR sensor

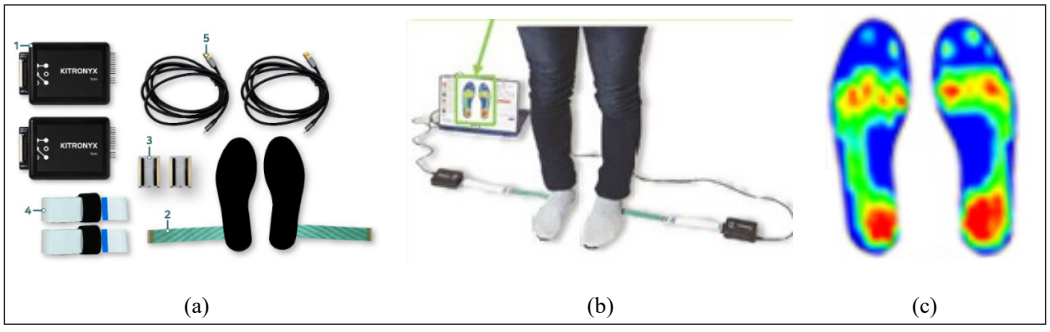


Figure 1. Kitronyx MP2513 Insole Sensor Kit: (a) Kit parts; (b) Kit usage; (c) real-time single frame of 16x20 foot pressure data captured
Source: Adapted from the website of Kitronyx.co.kr

array. Due to inherent hardware limitations, including multiplexed sensor scanning and signal stabilisation requirements, achieving sampling rates in the order of several hundred hertz is not practically feasible without significantly increasing system cost and complexity.

Prior to each experiment, the 16 × 10 FSR sensor array was calibrated under unloaded conditions. With no external force applied to the 16 × 10 FSR sensor array, all sensing elements were expected to produce an identical baseline output. Sensors exhibiting slight deviations due to manufacturing tolerances or electronic offsets were compensated via software-based offset calibration, ensuring all sensors shared the same baseline value under zero-load conditions.

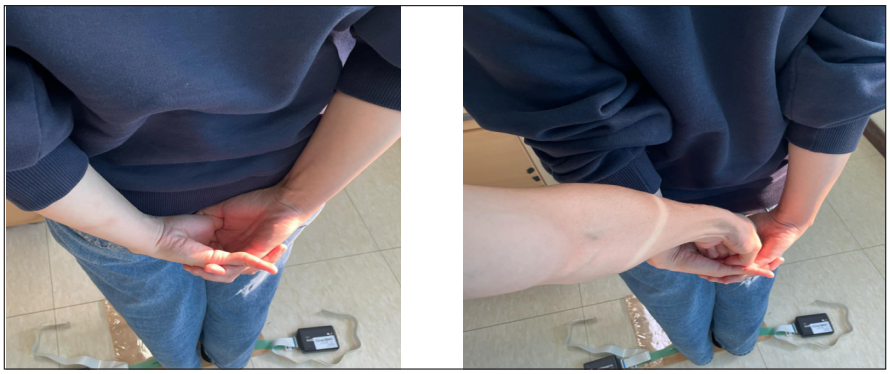
It is also noted that plantar pressure distribution may exhibit inherent asymmetry due to individual foot morphology and habitual stance patterns. To address this, baseline pressure distribution was recorded prior to perturbation and used as a subject-specific reference condition. All analyses were performed using relative deviations from this baseline, thereby reducing the influence of inter- and intra-individual asymmetry.

Perturbation Control

The downward push was applied manually to simulate a natural balance disturbance. To minimise potential bias, the experimenter applying the perturbation was blinded to the ground-truth condition (truthful vs non-truthful trial). To reduce variability in the magnitude of the applied force, the experimenter conducted repeated practice trials prior to data collection to ensure a consistent level of force across trials. While this approach cannot eliminate variability entirely, it was intended to maintain the perturbation within a consistent operational range. This approach is conceptually aligned with established experimental practices in polygraph testing, where efforts are made to standardise stimulus delivery (e.g. questioning tone and procedure) to reduce unintended variability.

Deception Task Protocol

To collect experimental data, a protocol was designed to mimic a traditional playful test using a mock crime paradigm with one physically healthy adult participant. The experimental procedure was conducted as follows. The subject is given two A4-sized sheets of paper and instructed to draw an apple on one sheet while leaving the other blank. Since the subject personally drew the apple on one of two sheets, the subject is aware of which sheet contains the apple drawing. However, the experimenter conducting the test is blinded to the sheet containing the apple. This is to prevent potential experimental bias. If the experimenter knew which sheet contained the apple, there would be a risk that they might unintentionally vary the magnitude of the downward push, which could influence the outcome of the experiment.



(a) (b)

Figure 2. Subject's Posture: (a) Standing upright with the subject's feet close together while clasping one's hands behind the back; (b) A short, forceful downward push applied to the clasped hands behind the back

Following this, the subject is instructed to stand upright with one's feet close together on the Kitronyx MP2513 (2024) Insole sensors while clasping one's hands behind one's back, as shown in Figure 2a. Plantar pressure data collection then commenced. This posture is selected to ensure that variations in balance primarily result from internal responses rather than external movement artefacts. A narrow base of support (feet close together) reduces lateral stability and increases reliance on fine postural control, thereby amplifying perturbation-induced balance responses. In addition, restricting arm movement minimises compensatory upper-body adjustments, allowing perturbation effects to be more directly reflected in plantar pressure distribution. Future work will compare shoulder-width stance and free-arm posture to evaluate the sensitivity-ecological validity trade-off.

Approximately 1s after the start of data recording, the experimenter asks the subject a single question: *"Have you truly draw an apple on this sheet?"* while pointing at one of two sheets. The subject is instructed to respond "*Yes, I did* " regardless of whether the sheet actually contains the apple. Between 3.0s and 3.8s, a short, forceful downward push is applied to the subject's clasped hands. This perturbation served as a controlled balance disturbance, simulating an unexpected postural shift and eliciting a natural balance response, as shown in Figure 2b.

The perturbation was applied approximately 3 seconds after trial initiation to ensure a stable baseline posture and allow the cognitive state (truthful vs non-truthful) to be active. Future studies will vary the timing of perturbations to analyse the temporal dynamics of cognitive influence.

For data interpretation, each trial is labelled based on whether or not the subject's verbal response matches their actual behaviour. Labels were binary: truthful or non-truthful. A trial is classified as truthful when the subject's verbal response is consistent with their actual behaviour. This included cases in which the subject responded "*Yes, I did* " when the experimenter pointed to the sheet containing the apple.

Conversely, a trial is classified as non-truthful when the subject's verbal response is inconsistent with the subject's actual behaviour. This included cases in which the subject responded "*Yes, I did*" when the experimenter pointed to the blank sheet on which the subject did not draw the apple.

In the present study, factors such as deliberate countermeasures, intentional balance control, and cognitive distraction were not explicitly addressed. These conditions pose known challenges not only for the proposed approach but also for conventional polygraph-based methods, in which intentional modulation of physiological responses remains an active area of research.

The experimental design employed a predetermined response paradigm, in which the subject was instructed to consistently answer "*Yes, I did*" regardless of the actual condition. This approach was adopted to ensure consistent verbal output across trials and to minimise variability associated with speech-related factors. Furthermore, the use of a fixed response was intended to simulate a simplified interrogation scenario under controlled conditions. While this design may introduce additional cognitive demand, it allows controlled comparison between conditions by reducing extraneous variability. Future work will incorporate more refined experimental paradigms, including variable response conditions and additional behavioural controls, to better approximate realistic settings and more precisely isolate deception-specific effects.

It is important to note that the mock crime task used in this study is intentionally simplified to maintain experimental control. While such a design does not fully replicate real-world investigative scenarios, which often involve stronger emotional and motivational factors, it enables isolation of the fundamental relationship between deception-related processes and postural responses. The present study should therefore be interpreted as a proof-of-concept feasibility study aimed at exploring whether plantar pressure patterns can serve as behavioural indicators of deception. These labels are listed in Table 1.

Table 1
The label of truthful or non-truthful trial

Label of a trial	Subject's Response	Subject's behaviour
Truthful	"Yes, I did"	Drew an apple on the sheet
Non-truthful	"Yes, I did"	Did not draw an apple on the sheet (left it blank)

Data Structuring and Visualisation

Data collection in each experimental trial lasts 6 seconds, during which 180 frames of foot pressure data are recorded. Each frame consists of a 16 × 20 matrix representing instantaneous pressure distribution across both feet, as shown in Figure 3(a).

To analyse these time series 180-frame sequences (noted as F_1, F_2, ⋯, F_{180}) visually, we transformed them into a structured grid of 60 rows (noted as R_1, R_2, ⋯, R_{60}) and 3 columns

(noted as C_1, C_2, C_3), which forms a 60x3 image matrix. This layout allowed the data to be viewed chronologically from bottom to top and left to right, preserving temporal continuity while offering a spatially compact representation. Each frame, F_i, is 1/30 s long, each row (R_i) having three columns (C_1, C_2, C_3) is 0.1s long, and 180 frames are 6s long. With that knowledge, frame F_1 at (R_1, C_1) is taken at $1/30$ s, frame F_2 at (R_1, C_2) at $2/30$ s, frame F_3 at (R_1, C_3) at $3/30$ s, frame F_4 at (R_2, C_1) at $4/30$ s, frame F_5 at (R_2, C_2) at $5/30$ s, frame F_6 at (R_2, C_3) at $6/30$ s, and so on. The final frame, F180, at (R60, C3) is captured at 6s. These frame indexing and timeline schemes for a 60 × 3 image matrix are illustrated in Figure 3(b). The mapping of frames to their indexed positions and time points facilitated quantitative and visual comparisons of postural balance responses between truthful and non-truthful trials.

Figure 3 illustrates the actual plantar pressure pattern of a subject maintaining an upright posture with feet close together without any external perturbation on clasped hands behind the back. When the body is in a balanced state, plantar pressure is evenly distributed across the foot, with comparable pressure levels in both the heel and toe regions. Also, greater foot pressure is observed on the right foot than on the left.

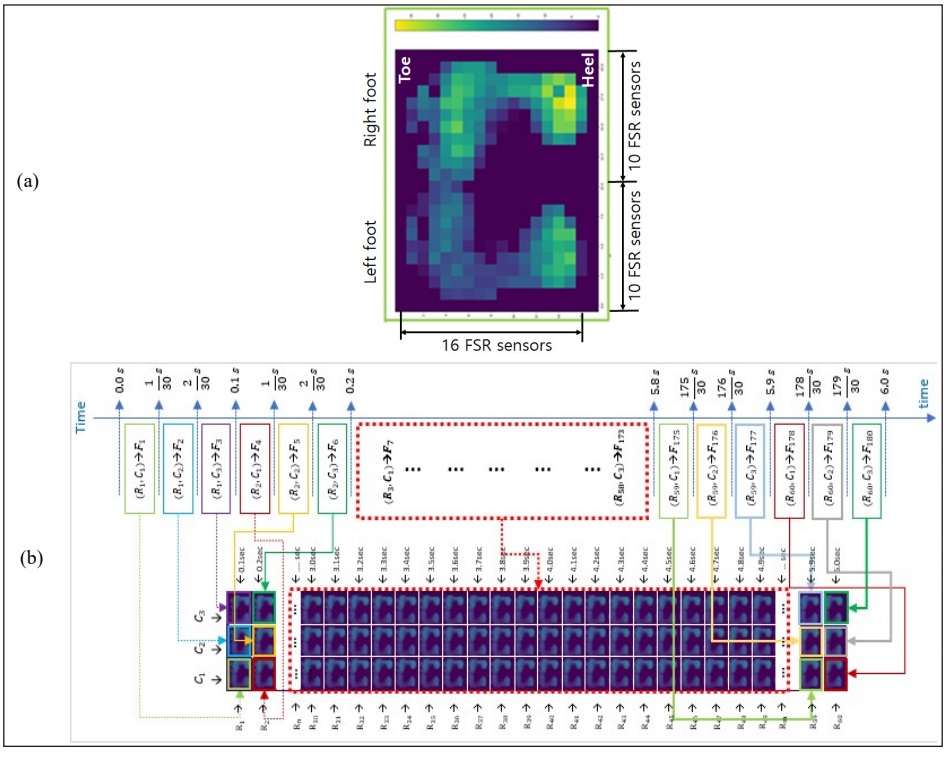


Figure 3. Frame indexing and timeline scheme for a 6s-long trial: (a) One frame of 16 × 20 FSR sensors (1/30s); (b) 180 sequential pressure frames (16 × 20 FSR sensor data) transformed into a 60 × 3 image matrix, which is organised by row(R1~R60) and column (C1~C3), progressing left to right and bottom to top in chronological order

Although the present study primarily relied on visual inspection as part of an exploratory analysis, the proposed 60 × 3 temporal representation naturally supports the extraction of several quantitative metrics that can enable objective statistical comparison, such as Centre of Pressure displacement/trajectory, Heel-toe pressure ratio, Recovery latency, Pressure variance, etc. In future work, these quantitative features will be systematically extracted and analysed using statistical methods and machine learning approaches to objectively distinguish between truthful and non-truthful conditions

RESULT AND DISCUSSIONS

Analysis of the structured 60 × 3 pressure matrices revealed distinct postural response characteristics between truthful and non-truthful trials, as shown in Figure 4 and Figure 5.

In a Truthful Trial

In a truthful trial shown in Figure 4(b), the subject is given two A4-sized sheets of paper and instructed to draw an apple on one sheet while leaving the other blank. And then stood upright with one's feet close together on the Kitronyx MP2513 (2024) Insole sensors while clasping one's hands behind one's back. Plantar pressure data collection then commenced. Approximately 1s after data recording began, the experimenter then pointed to the sheet containing the apple and asked the subject for the question: "*Have you truly draw an apple on this sheet?*". The subject responded, "*Yes, I did* ".

Around 3.1s, corresponding to frame F_{94} at (R_{32}, C_1), a short, forceful downward push was applied to the subject's clasped hands. Around $3.4\frac{1}{30}$ s, corresponding to frame F_{103} at (R_{35}, C_1), pressure in the toe region began to decrease. At approximately 3.5s, corresponding to frames $F_{106\text{-}108}$ at (R_{36}, C_1-C_3), pressure in the toe region nearly disappeared, while pressure was concentrated primarily in the heel region. This indicates a short-term backward shift of body weight.

However, postural balance was rapidly restored at approximately $3.7\frac{2}{30}$ s, corresponding to frame F_{110} at (R_{37}, C_2). By approximately 3.9s, corresponding to frame F_{115} at (R_{39}, C_1), plantar pressure returned to a more evenly distributed pattern across the feet, indicating complete recovery of postural stability.

The trial returned to baseline posture within approximately $0.4\frac{2}{30}$. The following perturbation reflects stable postural control and rapid balance recovery. In a truthful trial, the plantar pressure patterns exhibited quick stabilisation with minimal changes in postural pressure.

In a Non-Truthful Trial

In a non-truthful trial shown in Figure 4(a), the subject is given two A4-sized sheets of paper and instructed to draw an apple on one sheet while leaving the other blank. And

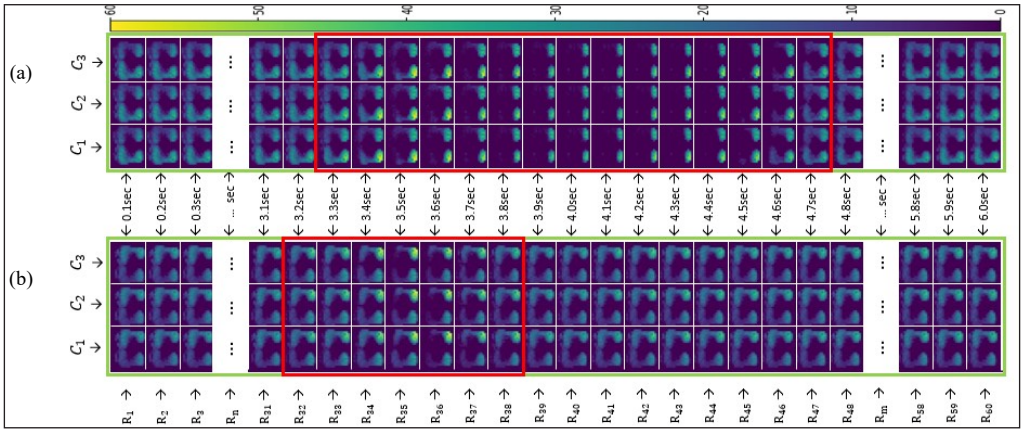


Figure 4. Comparisons of frame sequences from truthful and non-truthful trials: (a) The plantar pressure responses for the truthful trial; (b) The plantar pressure response for the non-truthful trial. Red-coloured regions highlight the plantar pressure responses following a short, forceful downward push applied to the clasped hands

then stood upright with one's feet close together on the Kitronyx MP2513 (2024) Insole sensors while clasping one's hands behind one's back. Plantar pressure data collection then commenced. Approximately 1s after data recording began, the experimenter then pointed to the blank sheet on which the subject had not drawn an apple and asked the same question: "*Have you truly drawn an apple on this sheet?*" The subject responded "*Yes, I did* ", thereby falsely claiming that an apple had been drawn on that sheet.

Around 3.2s, corresponding to frame F_{97} at (R_{33}, C_1), a short, forceful downward push was applied to the subject's clasped hands. At approximately $3.3\frac{1}{30}$ s, corresponding to frame F_{100} at (R_{34}, C_1), pressure in the toe region began to decrease. By approximately 3.4s, corresponding to frame F_{102} at (R_{34}, C_3), pressure in the toe region had further weakened.

From approximately $3.4\frac{1}{30}$ s to 4.1s, corresponding to frames $F_{103\text{-}121}$ from (R_{35}, C_1) to (R_{41}, C_3), pressure in the toe region nearly disappeared, while pressure became concentrated primarily in the heel region and began to decrease as the body moved further backwards. This indicates a pronounced backward shift of body weight. Around 4.1s, pressure in the heel region appears to be lowest, marking the initiation of forward recovery. Subsequently, from approximately 4.1s to 4.6s, corresponding to frame $F_{121\text{-}138}$ from (R_{41}, C_3) to (R_{46}, C_3), pressure in the heel region gradually increased again as the body attempted to regain balance.

At approximately $4.6\frac{1}{30}$s, corresponding to frame F_{139} at (R_{47}, C_1), pressure in the toe region reappeared and progressively increased in intensity. By approximately $4.7\frac{1}{30}$ s, corresponding to frame F_{142} at (R_{48}, C_1), plantar pressure distribution had returned to a baseline state, indicating recovery of postural stability.

Overall, the body began learning backwards at approximately $3.3\frac{1}{30}$. Following perturbation and initiated forward recovery at around 4.1s, with full stabilisation achieved near $4.7\frac{1}{30}$s. Compared to the truthful trial, the non-truthful trial exhibited a more pronounced backward displacement and delayed recovery.

The trial returned to baseline posture within approximately 1.4s following perturbation, reflecting a substantial loss of balance and slower stabilisation. In the non-truthful trial, the plantar pressure patterns showed greater deviation from baseline and larger fluctuations in postural loading than in the truthful trial.

These experimental results are listed in Table 2.

Table 2
Comparison of the time taken during foot pressure changes for one subject.

Label	Foot pressure change		
	Initiated	**Recovered**	**Duration**
Truthful	$3.4\frac{1}{30}$s	3.9s	$0.4\frac{2}{30}$ s
Non-truthful	$3.3\frac{1}{30}$s	$4.7\frac{1}{30}$ s	1.4s

Truthful .vs. Non-Truthful Trials with Three Additional Participants

The same experimental protocol was conducted with three additional participants. Although these additional trials were not included in the main analysis due to space limitations, consistent qualitative patterns were observed. Specifically, non-truthful responses exhibited larger backward displacement and slower postural recovery following perturbation compared with truthful responses. The experimental results from three additional participants are listed in Table 3 and depicted in Figure 5.

Despite inter-individual differences in baseline characteristics, a consistent trend was observed: recovery time under non-truthful trials was approximately 2-3 times longer than under truthful trials. A consistent increase in recovery time under non-truthful trials across

Table 3
The comparison in recovery time after the perturbation was applied to four subjects

Subject	Recovery Time		Ratio (Non-Truthful / Truthful)
	Truthful Trial	**Non-Truthful Trial**	
Subject A	0.5s	1.7s	3.4
Subject B	0.5s	1.3s	2.6
Subject C	0.4s	1.3s	3.25
Primary Subject	0.5s	1.4s	2.29

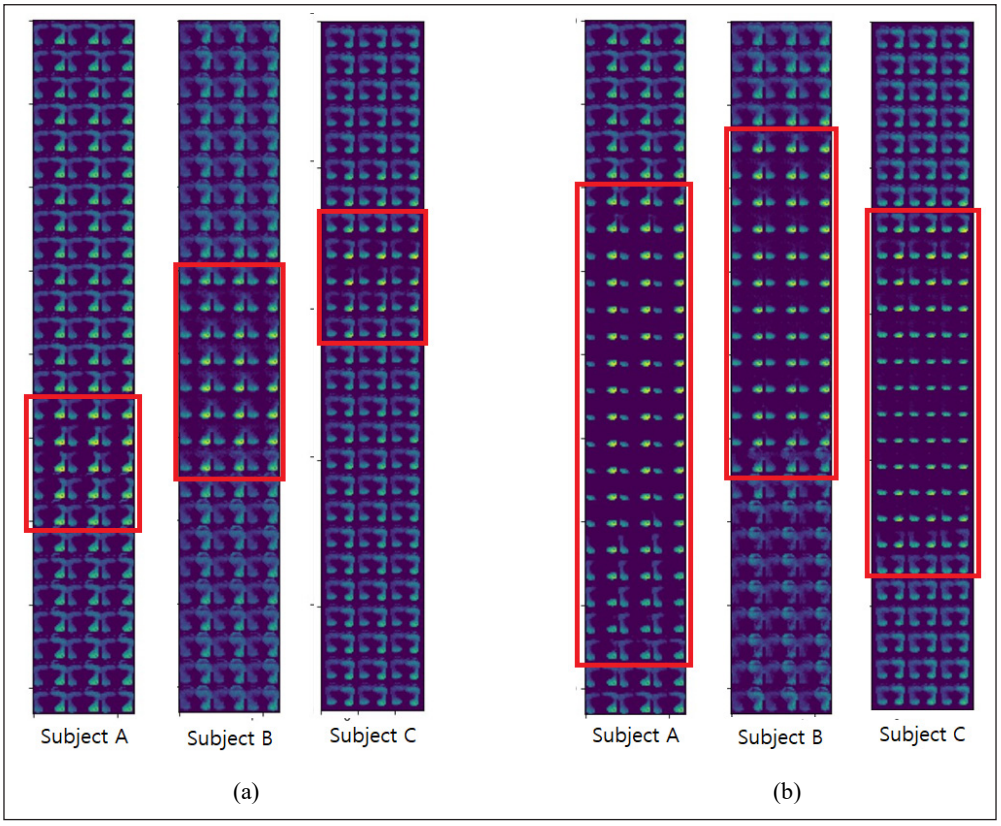


Figure 5. Comparisons of frame sequences from truthful and non-truthful trials for three additional subjects: (a) The plantar pressure responses for the truthful trial; (b) The plantar pressure response for the non-truthful trial. Red-coloured regions highlight the plantar pressure responses following a short, forceful downward push applied to the clasped hands

multiple participants suggests a potentially reproducible behavioural pattern rather than an individual-specific response. These observations suggest that the phenomenon reported in the primary experiment may not be limited to a single individual. The observed recovery time differences were consistently larger than intra-subject variability, suggesting that the effect may indicate a reproducible behavioural pattern.

Although the present analysis primarily focuses on anterior–posterior heel–toe pressure shifts, these dynamics are closely related to the trajectory of the centre of pressure (COP) along the anterior–posterior axis. Variations in heel–toe pressure distribution also provide indirect information on pressure variance across the foot during balance disturbance and recovery. While additional spatial characteristics such as mediolateral COP displacement and lateral sway may provide complementary information, the applied perturbation predominantly induced forward–backward postural adjustments. As a result, mediolateral

responses were relatively smaller and less sensitive for distinguishing between truthful and non-truthful conditions in the current experimental setup.

DISCUSSIONS

From the Viewpoint of the Theoretical Background

Deception is widely associated with increased cognitive load, as individuals must suppress truthful information while constructing and maintaining a false response. These processes rely on executive control functions, primarily mediated by prefrontal cortical networks, including working memory, inhibitory control, and conflict monitoring.

Postural control, although often considered an automatic motor function, depends on continuous sensorimotor integration involving the central nervous system. This includes integrating visual, vestibular, and proprioceptive inputs with motor outputs to maintain balance. Importantly, postural stability is not entirely independent of higher-level cognitive processes; prior studies have shown that increased cognitive load can interfere with motor coordination and balance regulation**,** particularly under conditions requiring rapid adaptation, such as perturbations.

From a neurophysiological perspective, cognitive load and motor control share limited neural and attentional resources. When cognitive demand increases—such as during deception—these shared resources may be partially reallocated from sensorimotor processes to cognitive control processes. This dual-task interference can reduce efficiency in postural regulation, resulting in delayed or less stable balance recovery following an external perturbation.

In the context of the present study, the key observation is not the initial loss of balance induced by the perturbation, which is expected in all conditions, but rather the difference in recovery dynamics**.** Specifically, deceptive responses may be associated with prolonged postural recovery, reflecting a temporary disruption in sensorimotor control due to increased cognitive demand.

This conceptual framework is consistent with principles underlying conventional polygraph-based approaches, which do not directly measure deception itself but instead infer it from relative changes in physiological responses associated with autonomic nervous system activation (e.g., heart rate, respiration, and skin conductance). Similarly, the present study does not assume a direct "deception signal," but rather examines behavioural changes in postural regulation that may arise from cognitive processes associated with deception.

While the current findings provide preliminary support for this interpretation, further studies involving larger participant samples and controlled cognitive conditions will be necessary to more precisely characterise the relationship between deception-related cognitive load and motor balance regulation.

From the Viewpoint of Experimental Results

The experimental results demonstrated consistent differences in postural recovery dynamics between truthful and non-truthful conditions. Truthful responses were associated with faster stabilisation and relatively symmetric pressure distribution, whereas non-truthful responses exhibited delayed recovery and greater deviation from baseline.

From a mechanistic perspective, these differences may arise from the combined influence of cognitive load and emotional arousal. Deceptive responses require suppressing truthful information and maintaining a false response, thereby increasing cognitive demand. At the same time, emotional factors such as anxiety, anticipation, or fear of being judged may further influence postural control. Therefore, the observed delayed recovery in non-truthful trials may reflect an interaction between cognitive and emotional processes rather than a single isolated factor.

Importantly, the present study adopts a within-subject comparison framework based on deviations from baseline, which helps reduce the influence of individual differences in emotional state or posture. However, the current design does not fully disentangle cognitive and emotional contributions. Future studies will incorporate controlled experimental conditions, including cognitive load-only tasks and emotion-inducing tasks without deception, to more precisely isolate these effects.

The current study focuses on two behavioural states (truthful vs non-truthful). However, additional conditions such as deliberate countermeasures, intentional balance control, and cognitive distraction may influence postural responses. These challenges are also present in conventional polygraph-based approaches, where intentional modulation of physiological responses remains an open issue. Future studies will therefore evaluate the robustness of plantar-pressure-based indicators under such conditions.

The mock crime task used in this study was intentionally simplified to maintain experimental control. While this design does not fully replicate real investigative scenarios, which involve stronger emotional and motivational factors, it allows isolation of the relationship between deception and postural response. Notably, even under these low-stakes conditions, consistent differences were observed. Future work will extend the paradigm to include higher-stakes and more ecologically valid scenarios.

It is important to emphasise that the present approach does not directly detect deception itself. Instead, it identifies behavioural correlates associated with cognitive and emotional processes underlying deceptive responses. This perspective is conceptually aligned with polygraph-based approaches, which infer deception from relative physiological changes rather than direct measurement.

To establish this method as a reliable deception detection approach, a comprehensive validation framework is required. This includes large-scale participant studies, standardised experimental protocols, quantitative feature extraction, statistical analysis, and machine

learning-based classification. In particular, sensitivity, specificity, and predictive reliability must be evaluated using cross-validation and independent datasets. Robustness under countermeasures and variability in experimental conditions must also be systematically assessed.

CONCLUSION

This study proposes a novel approach for deception detection based on plantar pressure pattern analysis using FSR sensors. The results demonstrate that non-truthful conditions are associated with delayed postural recovery and increased instability following perturbation. While preliminary, the results indicate a consistent behavioural pattern that may reflect underlying cognitive and emotional processes associated with deception.

Unlike conventional polygraph systems, the proposed method does not require electrodes or direct physiological monitoring, making it non-invasive, comfortable, and practical for real-world applications.

The present study should be interpreted as a proof-of-concept feasibility study, and substantial additional work is necessary to establish clinical- or forensic-level validity, including large-scale, diverse-participant studies and standardised experimental protocols. Future research will focus on large-scale validation, quantitative feature extraction, and machine learning-based classification to establish sensitivity, specificity, and predictive reliability. Additional studies will also examine the effects of cognitive load, emotional factors, and countermeasures to evaluate robustness under realistic conditions.

The present study demonstrates the feasibility of using plantar pressure–based postural dynamics as a behavioral indicator of deception.

ACKNOWLEDGEMENTS

This research was supported in part by the Soonchunhyang University Research Fund and in part by the National Research Foundation of Korea (NRF), funded by the Korean government (MSIT) (No.2021R111A3043994)

REFERENCES

Batgerel, G., & Kwon, C. (2026, February 7-9). *The use of FSR-based foot pressure patterns for deception detection* [Conference presentation]. International Conference on Next-generation Convergence Technology (ICNCT2026), Macau, China.

Gallardo-Antolín, A., & Montero, J. M. (2021). Detecting deception from gaze and speech using a multimodal attention LSTM-based framework. *Applied Sciences, 11*(14), Article 6393. https://doi.org/10.3390/app11146393

Grubin, D., & Madsen, L. (2005). Lie detection and the polygraph: A historical review. *The Journal of Forensic Psychiatry & Psychology, 16*(2), 357-369. https://doi.org/10.1080/14789940412331337353

Kim, Y. (2020). *LSTM based development of speech deception detection algorithm* [Master's thesis, Hanyang University].

Kitronyx Inc. (2024, June). *Quick start guide – MP2513 Insole Sensor Kit*. https://www.kitronyx.com/manual/?bmode=view&id=2850543

Krapohl, D., & Shaw, P. (2015). *Fundamentals of polygraph practice*. Academic Press.

Nam, B. R., Kim, J. Y., Kim, M. S., Choi, J., Cho, B. H., & Kim, I. Y. (2021). Technical note: Development of non-contact deception detection using facial expression and analysis of significant time period. *Journal of Science Criminal Investigation, 15*(3), 238-243. https://doi.org/10.20297/jsci.2021.15.3.238

Owayjan, M., Kashour, A., Al Haddad, N., Fadel, M., & Al Souki, G. (2012). The design and development of a lie detection system using facial micro-expressions. In *2012 2nd International Conference on Advances in Computational Tools for Engineering Applications (ACTEA)* (pp. 33-38). IEEE. https://doi.org/10.1109/ICTEA.2012.6462897