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**NIST Internal Report**
**NIST IR 8491**


# Face Analysis Technology Evaluation (FATE)

*Part 10: Performance of Passive, Software-Based Presentation Attack Detection (PAD) Algorithms*


Mei Ngan
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Austin Hom



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NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

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## Abstract

This report quantifies the accuracy of passive face presentation attack detection (PAD) algorithms (software only, no hardware solutions) operating on conventional 2D imagery of various presentation attack instruments (PAI). The algorithms were submitted to the Presentation Attack Detection track of the Face Analysis Technology Evaluation (FATE) executed by the National Institute of Standards and Technology (NIST).

## Acknowledgements

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And last but never the least, the authors would like to thank Jack Allen and Jim Matey for their time and candor in reviewing the contents of this report and for providing many meaningful suggestions to help make this a better publication.

## Other Relevant Reports

Results from the Face Recognition Technology Evaluation (FRTE) and Face Analysis Technology Evaluation (FATE) activities appear in the series of NIST Interagency Reports tabulated below. From 1999 to July 2023, FRTE and FATE were collectively known as FRVT.

| Date | Link | Title | NISTIR |
|---|---|---|---|
| 2014-03-20 | PDF | FATE Performance of Automated Age Estimation Algorithms | 7995 |
| 2015-04-20 | PDF | FATE Performance of Automated Gender Classification Algorithms | 8052 |
| 2014-05-21 | PDF | FRTE Performance of Face Identification Algorithms | 8009 |
| 2017-03-07 | PDF | Face In Video Evaluation (FIVE) Face Recognition of Non-Cooperative Subjects | 8173 |
| 2017-11-23 | PDF | The 2017 IARPA Face Recognition Prize Challenge (FRPC) | 8197 |
| 2020-01-03 | Draft | FRTE - Part 1: Verification | Draft |
| 2019-09-11 | PDF | FRTE - Part 2: Identification | 8271 |
| 2019-12-11 | PDF | FRTE - Part 3: Demographic Effects | 8280 |
| 2020-03-04 | PDF | FATE - Part 4: MORPH - Performance of Automated Face Morph Detection | 8292 |
| 2020-03-06 | Draft | FATE - Part 5: Face Image Quality Assessment | Draft |
| 2020-07-24 | PDF | FRTE - Part 6A: Face Recognition Accuracy with Face Masks using Pre-COVID-19 Algorithms | 8311 |
| 2022-01-20 | PDF | FRTE - Part 6B: Face Recognition Accuracy with Face Masks using Post-COVID-19 Algorithms | 8331 |
| 2022-07-13 | PDF | FRTE - Part 7: Identification for Paperless Travel and Immigration | 8381 |
| 2022-09-30 | PDF | FRTE - Part 8: Summarizing Demographic Differentials | 8429 |
| 2022-09-30 | PDF | FRTE - Part 9A: Face Recognition Verification Accuracy on Distinguishing Twins | 8439 |
| 2023-09-20 | PDF | FATE - Part 10: Performance of Passive, Software-based Presentation Attack Detection (PAD) Algorithms | 8491 |
| 2023-09-20 | PDF | FATE - Part 11: Face Image Quality Vector Assessment: Specific Image Defect Detection | 8485 |

Details appear on pages linked from https://www.nist.gov/programs-projects/face-projects.


## Key words

Face Analysis Technology Evaluation; FATE; PAD; presentation attack detection.

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## Executive Summary

### Overview

This report documents the ability of software-based algorithms (software only, no hardware solutions) to detect the presence of presentation attacks in conventional 2D still and video imagery of human faces. For 82 prototype algorithms from 45 developers, the report surveys the trade-off between false alarm rates on legitimate non-attack images and detection rates on images of various presentation attack instruments (PAIs). All PAIs are detailed in the public domain, such that developers could have implemented defenses against them. The study was executed offline using archived images sequestered at NIST. It did not evaluate approaches based on 3D, near-infrared illumination, nor those based on real-time human interaction with a camera including challenge-response, variable illumination, and automated adjustment of the imaging system.

### Motivation

As face recognition algorithms become ever more capable, they have been employed in remote enrollment and authentication applications in which the capture is not supervised by a trusted attendant. In such settings, an attacker can present arbitrarily modified faces to a camera. This is done either with the intent of ***impersonation*** of another person (e.g., fradulent bank account access) or ***evasion*** in which the user is trying to not be recognized (e.g., entering a casino). Accordingly, the ISO/IEC 30107[1] series of standards define a presentation attack (PA) as "the presentation of an artefact or of human characteristics to a biometric capture subsystem in a fashion intended to interfere with system policy". The standards also establish requirements on evaluations of PA detection approaches and metrics to summarize their accuracy.

### Notable Observations and Results

PAD accuracy varies widely across algorithms, use cases (impersonation vs. evasion), and PA types. The detection of some PA types - photo print/replay attacks, protective face masks, and flexible silicon face masks - is well supported across multiple developers, while other PA types generated high detection error rates with all tested implementations. Many algorithms generate lower error rates when the input imagery is a video sequence when compared to a single still image from the same collection event. Additionally, by applying simple sum-rule fusion of PAD scores across multiple algorithms, the outcomes from fusion outperformed the top performing algorithm in all impersonation PA categories and in most evasion PA categories. A more detailed summary of results follows in the Technical Summary.

## Technical Summary

### Who Should Read This Report

This report covers PAD capabilities for **software-based** detection of **physical attacks** presented to the camera, without any interaction with the user or the hardware sensor. In short, algorithms are provided with a pre-existing image or video and make a PAD determination based solely on the information in the input imagery. As such, this report does not assess capabilities of hardware-enabled mechanisms that can alter optics or illumination during capture. Additionally it is silent on non-presentation attacks - e.g. those that subvert operation of software post-capture including injection attacks. Nevertheless passive, software-based PAD has a role in those applications where a commodity or non-biometric camera is used for collection of an image that is then transmitted to a receiving system. For example, if a passport photo is collected in a retail outlet using a generic portrait camera, the passport issuer may check for presentation attack.

Likewise in some countries' border control points, the capture subsystem may not include a (hardware) PAD module, instead relying on remote server-side PAD operating solely on the image. While software-based PAD is relevant in some operational settings, it only represents a small part of a much larger presentation attack technology landscape. Figure 1 guides readers in the relevance of this report.

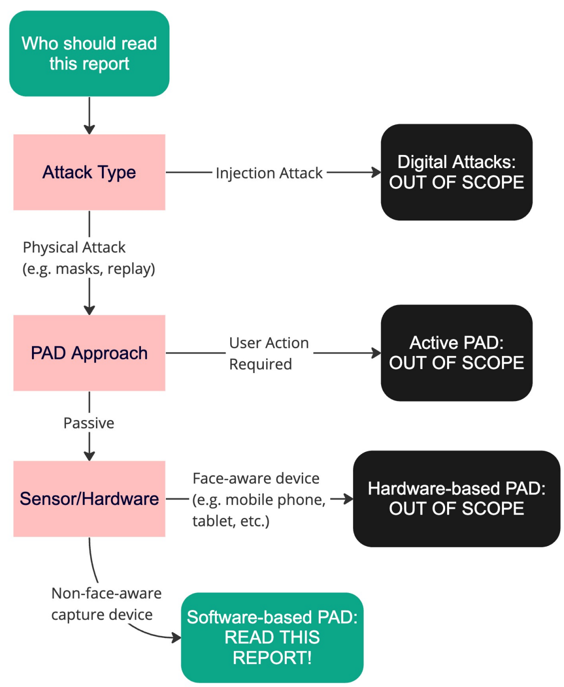



**Fig. 1.** Scope of this report.

### What We Did

The NIST Information Technology Laboratory (ITL) quantified the accuracy of passive, software-based face presentation attack detection (PAD) algorithms applied to imagery of different presentation attack instruments (PAI). FATE PAD was open for participation worldwide between January 3rd, 2023 to February 28th, 2023, and developers were allowed to submit up to two algorithms for evaluation. Feedback in the form of algorithm report cards was provided to developers after each algorithm completed the trials. FATE PAD had two separate tasks that evaluated algorithms with an ability to detect 1) impersonation attacks and 2) evasion attacks. Developers could submit algorithms to one or both tasks. NIST evaluated 82 algorithms from 45 unique developers worldwide. All algorithms implemented the impersonation detection task, and 27 of those algorithms also implemented the evasion detection task.

Our evaluation dataset contained imagery (primarily stills) of approximately 20 000 PA attempts and 21 000 bona fide presentations, which included 9 categories of PAs. The attacks used in this test are documented in the public domain. For PA types tested where detection appears to be well-supported by multiple developers, the PA descriptions are disclosed. For the remaining PA types, detection metrics are reported but without the name or description of the attack instrument.

## How We Stated Performance

We used the PA attempts to estimate the Attack Presentation Classification Error Rate (APCER) or PA miss rate. We used the bona fide presentations to estimate the Bona Fide Presentation Classification Error Rate (BPCER) or false detection rate.

BPCER can be interpreted as the rate of inconvenience for legitimate users of the system whose presentation is being incorrectly detected as a PA. The consequence of such false detections is additional resources required to adjudicate the bona fide sample or unnecessary re-attempts or re-collection of the biometric sample. Conversely, APCER is the rate that fraud successfully takes place when a PA is incorrectly classified as a legitimate, bona fide sample. BPCER often gives a statement of the convenience of a system while APCER represents the security of a system.

The metrics are defined in the ISO/IEC 30107-3[2] standard. As in other decision systems, the two error rates can be traded off against each other - one goes up, the other goes down - by changing a decision threshold. The report includes figures showing this tradeoff and also two summary measures:

- ▷ **APCER @ BPCER = 0.01**, a convenience-focused metric that reports the proportion of undetected PAs when the false detection rate is limited to 1% of bona fide imagery. The approach of controlling BPCER (by setting an appropriate threshold) is important in those applications where the system owner cannot tolerate high rejection rates of legitimate bona-fide submissions, and when the attendant costs of undetected fraud are not punitive or if a priori PA-based fraud is rare (e.g., eGate operations).
- ▷ **BPCER @ APCER = 0.01**, a security-focused metric that reports the proportion of bona fide images incorrectly flagged as PAs when the PA miss rate is limited to 1% of PA imagery. The approach of controlling APCER by setting a threshold sufficient to detect a majority of PAs is important in those applications where rejection of bona-fide submissions is acceptable and when fraud costs associated with PA presentation are large (e.g., bank account access).

## What We Found

**Detection Performance:** PAD performance varied widely across algorithms, use cases, and PA types, with only a small percentage of algorithms evaluated demonstrating notable detection capabilities. Tables 1 and 2 tabulate the top performing algorithm results for each PA type tested under the impersonation and evasion tasks, respectively.

PA types where detection appears to be well-supported by multiple developers (for either impersonation or evasion) are disclosed in the description column. For the remaining PA types, detection metrics for each PAI are reported but without description of the actual PAI. *Section 5.1*

**Table 1.** Top Performers - Use Case: detectImpersonationPA - Media Type: stills

| PA Type | Description | Algorithm | (Convenience) APCER @ BPCER=0.01 | Algorithm | (Security) BPCER @ APCER=0.01 |
|---|---|---|---|---|---|
| PA Type 1 | | kakao-001 | 0.07 | iproov-000 | 0.069 |
| PA Type 3 | Flexible Silicone Face Mask | stcon-001 | 0.0 | stcon-001 | 0.0003 |
| PA Type 4 | | cyberlink-002 | 0.13 | aware-001 | 0.200 |
| PA Type 7 | | cyberlink-002 | 0.012 | cyberlink-002 | 0.012 |
| PA Type 8 | Photo Print/Replay Attack | alice-001<br>idemia-011<br>idrnd-000<br>idrnd-001 | 0.0 | idrnd-001 | 0.0001 |
| PA Type 8 (zoomed) | Photo Print/Replay Attack (zoomed) | idrnd-001 | 0.005 | idrnd-001 | 0.006 |

**Table 2.** Top Performers - Use Case: detectEvasionPA - Media Type: stills

| PA Type | Description | Algorithm | (Convenience) APCER @ BPCER=0.01 | Algorithm | (Security) BPCER @ APCER=0.01 |
|---|---|---|---|---|---|
| PA Type 1 | | kakao-001 | 0.13 | kakao-001 | 0.151 |
| PA Type 2 | | kakao-001 | 0.12 | alice-000 | 0.035 |
| PA Type 3 | Flexible Silicone Face Mask | onfido-000 | 0.05 | alice-000 | 0.014 |
| PA Type 4 | | kasikornlabs-000 | 0.62 | aware-001 | 0.191 |
| PA Type 5 | | kakao-001 | 0.0 | kakao-001 | 0.0005 |
| PA Type 6 | Protective Face Mask | rankone-000<br>rankone-001 | 0.0 | rankone-000 | 0.000 |
| PA Type 7 | | kakao-001 | 0.14 | cyberlink-002 | 0.035 |
| PA Type 8 | Photo Print/Replay Attack | kakao-000 | 0.009 | kakao-000 | 0.006 |
| PA Type 8 (zoomed) | Photo Print/Replay Attack (zoomed) | onfido-001 | 0.06 | kakao-001 | 0.052 |

| | | | | |
|---|---|---|---|---|
| PA Type 9 | kasikornlabs-000 | 0.052 | cyberlink-002 | 0.028 |

**Performance across PA Types:** The detection of some PA types (i.e., photo print/replay attacks, protective face masks, and flexible silicone face masks) appears to be well supported by multiple developers, with relatively low error rates (APCER $\leq$ 0.01 @ BPCER=0.01 and BPCER $\leq$ 0.01 @ APCER=0.01) achieved by multiple developers. There are some PAs where detection is supported by only a limited number of developers (e.g., PA Type 7) and in some cases, by only a single developer (e.g., PA Type 5). However, there remain a number of PAs evaluated where detection error rates are high across all algorithms tested, indicative that some PAs still pose a threat to passive, software-based PAD approaches. *Section 5*

**Photo Print/Replay Attacks:** Detection of photo print/replay attacks where the frame of the printed photo/electronic tablet and the subject's hands are visible is well supported by multiple developers. However, when the view is zoomed in such that the frame of the printed photo/electronic tablet and the subject's hands are not visible, detection error rates increase across all algorithms, and in some cases, quite significantly. *Section 5*

**Still vs. Video Imagery:** A number of algorithms generate improved error rates when the input imagery is a video sequence when compared to a single still image from the same collection event. The existence and extent of PAD error reduction in videos versus stills is highly algorithm-dependent. *Section 5.3*

**Fusion:** We investigated to what extent fusion of multiple PAD algorithms might improve detection outcomes. Using simple sum-rule fusion of PAD scores from four more accurate algorithms applied to the same image, the accuracy of the combined algorithm exceeded that of the top performing algorithm in all impersonation PA categories and in most evasion PA categories. *Section 5.4*

**Demographic Effects:** While demographic effects was not a primary evaluation objective, first-order analysis of results was conducted on bona fide imagery to assess whether false detection rates (BPCER) vary across the race and sex groups represented in the test data. We analyzed BPCER for different race-sex groups at a fixed threshold that gave BPCER equal (or closest) to 0.03 on white males. False detection results across demographic groups varied across algorithms, and no obvious trends were observed in terms of elevated false detection rates isolated to a particular demographic group. *Section 5.5*

**Impersonation vs. Evasion Results:** PAD implementations are often fielded in applications where the classes of risk are known. For example, in authentication, a primary concern is impersonation. In background checks, the concern is of evasion/concealment. Presentation attack detection with the intent of impersonation vs. evasion was implemented and evaluated as separate functions. PAs used to evaluate impersonation detection were also used to test evasion detection on the basis that successful impersonation would also constitute evasion. When tested on the same PAs, algorithms looking for the presence of impersonation generally performed better than those detecting evasion. For algorithms that implemented both impersonation and evasion detection functions, differences in error rates were also observed when tested on the same PAs for the same algorithm. This is evidence that the different functions are potentially targeting specific types of attacks.

### Limitations

As our evaluation tested PAD capabilities under narrow conditions, this study doesn't fully capture the entire PAD technology landscape. Particularly the following points should be considered:

▷ **Digital attacks:** Digital "injection attacks" that feature a direct electronic introduction of a digital image or video, while an important aspect of the presentation attack landscape, were not evaluated.

▷ **Hardware-based PAD:** If PAD is deployed on a face-aware device (e.g., mobile device), there are opportunities to employ more sophisticated hardware-based PAD approaches that involve other sensors (e.g. time-of-flight), other illuminants (e.g. near infrared), other non-standardized data (e.g. lip movement) or signals sensed by the hardware (e.g., flashing lights). Our study did not evaluate hardware-based PAD approaches.

▷ **Active PAD:** In applications where the user is able to interact with the system in real-time, some PAD implementations can require the user to perform certain actions to prove their "liveness" such as asking the user to blink or turn their head. Such active challenge-response PAD approaches were not evaluated in our study.

# 1. Presentation Attack Detection (PAD)

## 1.1. Introduction

A presentation attack (PA), as defined by the ISO/IEC 30107[1] standard on biometric presentation attack detection, is ”the presentation of an artefact or of human characteristics to a biometric capture subsystem in a fashion intended to interfere with system policy”. A presentation attack is often launched with the intent of ***impersonation*** (the user is trying to authenticate as a target identity) or ***evasion*** (the user is trying to fool the biometric system into not recognizing their true identity). The goals of impersonation include trying to gain positive access privilege as someone else, for example, trying to unlock someone's cell phone or gain access to a facility. The goals of evasion are typically to conceal one's true identity to evade recognition from say a watchlist, or to create a separate enrollment under a different name. Biometric systems can be attacked by any of an open-ended set of presentation attack instruments, the number and type of which is determined by the effort and ingenuity of the attacker and the countermeasures instituted by the developer. Some examples of known presentation attack instruments include artificial ”gummy” fingers[3] , ”replay” attacks where the attacker is holding a photo or video of someone's face to the camera, and iris photo and contact lens attacks.

Presentation attack of face recognition systems and the mechanisms to detect it are areas of high interest given the widespread deployment of face recognition systems, particularly in unmanned and unsupervised scenarios such as online remote enrollment and authentication.

## 1.2. Scope

### 1.2.1. Physical (Analog) vs. Digital Attacks

Presentation attacks are defined to include creation and introduction of physical artefacts to the sensor in the analog domain. Examples of this include donning a silicone face mask or holding up a printed photo or tablet display to the camera. As presentation attack methods evolve, attackers will also work to exploit weaknesses in the implementation after the sensor i.e., in the digital domain. These ”injection attacks” feature a direct electronic introduction of a digital image or video. These are recently of particular concern in personal devices where a virtual camera is not readily distinguishable from the physical camera. This is a possibility in those scenarios where the capture cannot be trusted - for example in some mobile phones - because the integrity of the sensor/camera cannot be guaranteed. The FATE PAD activity evaluated physical attacks with analog artifacts. Digital injection attacks, while an important aspect of the presentation attack landscape, are out of scope for this evaluation.

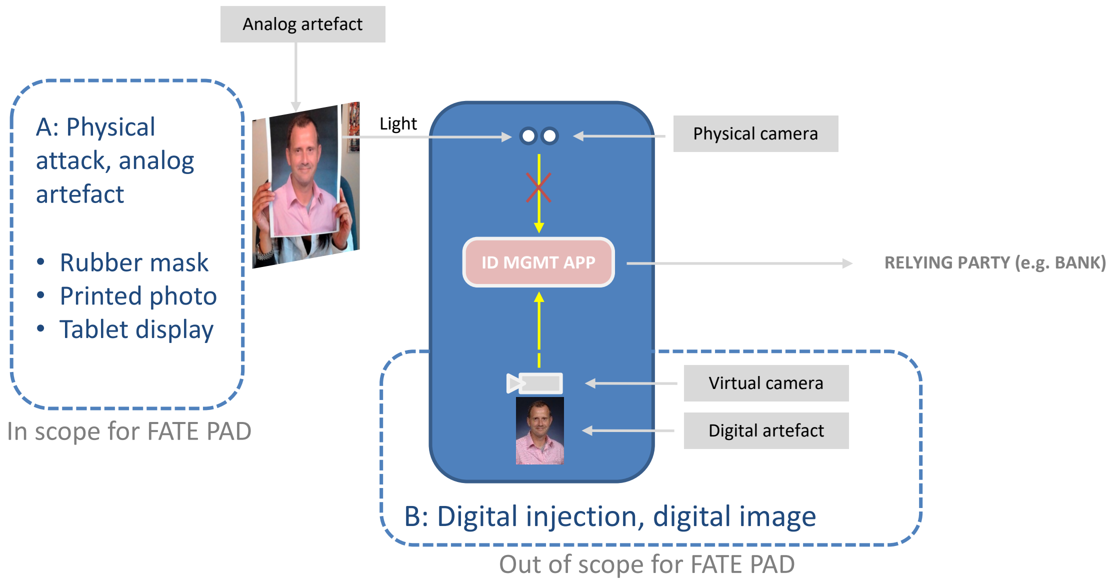



**Fig. 2.** Analog versus digital attacks

### 1.2.2. Passive PAD Approaches vs. User Interaction Required PAD

In applications where the user is able to interact with the system in real-time, some PAD implementations require the user to perform certain actions to prove their ”liveness” such as asking the user to blink or turn their head. These are challenge-response approaches in which an attacker must emulate the expected response to the challenge.

However, in scenarios where user interaction is not possible and the PAD system can only operate on captured imagery (often without the user’s awareness), this is known as passive PAD. In this test, we evaluated passive PAD approaches that operated on pre-collected imagery without any sort of user interaction. PAD approaches that require user interaction are out of scope for FATE PAD.

### 1.2.3. Software vs. Hardware-based PAD

PAD capabilities generally fall into two categories – software-based and hardware-based PAD. Table 3 summarizes the relevance and applications of software vs. hardware-based PAD. The FATE PAD activity provided independent testing of software-based facial PAD detection technologies. The evaluation is designed to assess ***software-based*** PA detection capability to inform developers and current and prospective end-users. Software-based PAD solutions operate only on the captured imagery. Hardware-based PAD solutions are out of scope for FATE PAD.

Software-based PAD has a role in those applications where a commodity or non-biometric camera is used for collection of an image that is then transmitted to a receiving system. For example, if a passport or other ID photo is collected in a retail outlet using a generic portrait camera, the passport issuing agency may check for PA. Likewise in some countries' border control points, the capture subsystem may not include a (hardware) PAD module, instead relying on remote server-side PAD operating solely on the image.

| | Software-based PAD | Hardware-based PAD |
|---|---|---|
| Input | Image/video | Image/video and other non-standardized data or signals sensed by dedicated hardware (e.g., flashing lights) |
| Mode of operation | Server-based or cloud-based PAD with non-face-aware capture device; offline PAD in existing/legacy systems | Client or edge-based PAD with dedicated face-aware capture device |
| Applications | Applications where capture processes and devices are not controlled or cannot be configured to perform PAD | Applications where hardware is controllable/configurable during the capture process to perform PAD |

**Table 3.** Software vs. hardware-based PAD

### 1.2.4. Offline Testing

FATE PAD was conducted as an offline evaluation at a NIST facility by applying algorithms to still photos and video frames that are sequestered on computers controlled by NIST. Offline evaluations are attractive, because they allow uniform, fair, repeatable, and large-scale statistically robust testing. However, they do not capture all aspects of an operational system. Offline tests do not include a live image acquisition component or any interaction with real users. Our approach is adopted to allow evaluation on large datasets and to achieve repeatability where all algorithms are tested against the same evaluation datasets. Testing was performed on high-end server-class blades running the Ubuntu Linux [4] operating system. The test harness used concurrent processing to distribute workload across dozens of computers.

## 2. Datasets

The Presentation Attack Instruments (PAI) used in this test are documented in the public domain. Due to data sensitivities, our intention was to not disclose the PAIs used in our evaluation. This was intended to encourage broad PAD effectiveness across unknown PAs and to discourage tuning to specific attacks. This reflects the operational reality that attackers don't advertise their methods. However, after evaluation of current PAD capabilities, we have decided to disclose a subset of the PA types where detection appears to be well-supported by multiple developers. For the remaining PA types, detection metrics for each PAI are reported but without the name or description of the PAI. PAs used to evaluate impersonation detection were also used to test evasion detection, because by definition, impersonation is also a form of evasion (by trying to look like someone else, you're also trying to not look like yourself). See Tables 4, 5, and 6.

**Table 4.** Dataset - Bona Fides

| Description | Media Type | Num. Media |
|---|---|---|
| Bona Fide | stills | 21218 |
| Bona Fide | videos | 538 |

**Table 5.** Dataset - Use Case: detectImpersonationPA

| Label | Description | Media Type | Num. Media |
|---|---|---|---|
| PA Type 1 | | stills | 1119 |
| PA Type 3 | Flexible Silicon Face Mask | stills | 207 |
| PA Type 4 | | stills | 619 |
| PA Type 7 | | stills | 4573 |
| PA Type 8 | Photo Print/Replay Attack | stills | 1417 |
| PA Type 8 (zoomed) | Photo Print/Replay Attack (zoomed) | stills | 1417 |
| PA Type 1 | | videos | 15 |
| PA Type 3 | Flexible Silicone Face Mask | videos | 10 |
| PA Type 8 | Photo Replay Attack | videos | 54 |

**Table 6.** Dataset - Use Case: detectEvasionPA

| Label | Description | Media Type | Num. Media |
|---|---|---|---|
| PA Type 1 | | stills | 3310 |
| PA Type 2 | | stills | 105 |
| PA Type 3 | Flexible Silicon Face Mask | stills | 207 |
| PA Type 4 | | stills | 619 |
| PA Type 5 | | stills | 256 |
| PA Type 6 | Protective Face Mask | stills | 1209 |
| PA Type 7 | | stills | 4629 |
| PA Type 8 | Photo Print/Replay Attack | stills | 1417 |
| PA Type 8 (zoomed) | Photo Print/Replay Attack (zoomed) | stills | 1417 |
| PA Type 9 | | stills | 6473 |
| PA Type 1 | | videos | 56 |
| PA Type 3 | Flexible Silicon Face Mask | videos | 10 |

| | | | |
|---|---|---|---|
| PA Type 5 | | videos | 51 |
| PA Type 8 | Photo Replay Attack | videos | 54 |
| PA Type 9 | | videos | 38 |

## 2.1. Description of Disclosed PAIs

**Photo Print/Replay Attack:** Imagery includes subjects presenting a printed photo or digital photo displayed on a high resolution electronic tablet to the camera. The frame of the printed photo/electronic tablet and the subject's hands are typically visible.

**Photo Print/Replay Attack (zoomed):** Imagery includes subjects presenting a printed photo or digital photo on a high resolution electronic tablet to the camera, zoomed in such that the frame of the printed photo/electronic tablet and the subject's hands are not visible.

**Protective Face Mask:** Imagery includes subjects wearing commonly-used protective face masks, including disposable surgical masks and solid and patterned fabric masks. Patterns on masks did not include any facial features.

**Flexible Silicon Face Mask:** Imagery includes subjects wearing flexible silicone whole-head face masks.

## 2.2. Description of Imagery

All imagery is collected with a color camera that is in a fixed position, and only color images and videos are used in the evaluation. Stills and videos contain a single, cooperative subject, with neutral expression, approximately centered in the field of view. Still image dimensions range from 640x480 to 5184x3456.

Video sequences are variable length across all samples provided. Videos only contain entirely bona fide attempts or entirely presentation attack attempts. The use of compression is operationally realistic for those applications where PAD operates on received media rather than a live-captured stream direct from the sensor. All videos in this test were compressed with h264, with compression ratios in the range of 30:1 to 50:1. Video frame rate was provided as input to the algorithm in frames per second (fps). Frame rates range from 24 fps to 60 fps, with typical frame rate of 24 frames per second. Video duration ranges from 3 seconds to 30 seconds, with typical duration of 25 seconds. Video frame width and height in pixels are provided to the algorithm. Video frame dimensions range from 1920x1080 (1080p) to 3840x2160 (4K).

## 3. Metrics

In this section, we adopt terminology from the presentation attack detection testing standard[2] to quantify PAD accuracy. Presentation attack detection requires submitted algorithms to determine whether a particular sample contains a presentation attack or not. Given an image or a video, algorithms reported 1) a binary decision on whether the sample contains a PA or not and 2) a confidence score on $[-1,1]$ representing the algorithm's certainty about whether the sample is a PA $[+1]$ or not $[-1]$ or indeterminate [0]. A low score $[-1]$ indicates certainty that the media does not contain a PA, and a high score $[+1]$ represents certainty that the media does contain a PA.

This report computes and reports the following metrics:

### 3.1. Attack Presentation Classification Error Rate (APCER)

APCER is defined as the the proportion of presentation attack samples incorrectly classified as bona fide presentation

### 3.2. Bona Fide Presentation Classification Error Rate (BPCER)

BPCER is defined as the proportion of bona fide samples incorrectly classified as presentation attack samples

### 3.3. Failure to Process Events

Attack Presentation Non-Response Rate (APNRR) and Bona Fide Presentation Non-Response Rate (BPNRR) are defined as the proportion of presentation attack and bona fide samples, respectively, that do not generate a response and fail to be processed by the algorithm software, whether it's elective refusal to process the imagery or an involuntary error. Failure to process events are logged when the algorithm software returns a nonsuccessful return code from the PAD function, indicating that something went wrong while processing the imagery for PAD. ISO/IEC 30107-3[2] includes APNRR as ”proportion of attack presentations using the same PAI species that cause no response at the PAD subsystem or data capture subsystem” to quantify outcomes where the sensor is not even triggered by the presented PA sample. We use APNRR to quantify that for the PAD-subsystem, which here is the algorithm under test.

Failure to process events are incorporated into the calculation of BPCER and APCER. All occurrences of failure to process by an algorithm are treated as if a presentation attack is detected with the confidence score set to +1. This implements a failure-is-considered-suspicious policy.

## 3.4. Detection Error Tradeoff (DET)

We assess detection accuracy by analyzing the confidence score returned by the algorithm. In this case, the higher the confidence value, the more likely the algorithm thinks the sample contains a PA. A reasonable approach to the detection problem is to classify a sample as either a PA or bona fide sample by thresholding on its confidence value.

Given $N$ detection scores on bona fide imagery, $b$, the BPCER is computed as the proportion above some threshold, $T$. Similarly, given $P$ detection scores on PA imagery, $p$, the APCER is computed as the proportion below some threshold, $T$. $H(x)$ is the unit step function[5], and $H(0)$ is taken to be 1.

$$\text{BPCER}(T) = \frac{1}{N}\sum_{i=1}^{N} H(b_i - T), \tag{1}$$

$$\text{APCER}(T) = 1 - \frac{1}{P}\sum_{i=1}^{P} H(p_i - T). \tag{2}$$

Operationally, there are two primary types of errors to be considered for presentation attack detection - BPCER and APCER. BPCER, which gives an indication of how often a legitimate user of the system is inconvenienced as an incorrectly flagged attack. The consequence of such false detections is additional resources required to adjudicate the bona fide sample or unnecessary re-attempts or re-collection of the biometric sample. Conversely, APCER is the rate that fraud successfully takes place when a PA is incorrectly classified as a legitimate, bona fide sample. BPCER often gives a statement of the convenience of a system while APCER represents the security of a system.

In applications where large volumes of (presumably legitimate) transactions occur (e.g., eGate operations), a PAD system would typically be configured at thresholds to minimize BPCER or false detection rate. BPCER could be limited to some percentage that is commensurate with the amount of resources available to conduct secondary processes. We consider these ***convenience-focused*** use cases.

In applications where the focus is to minimize undetected presentation attacks (e.g., bank account access), then a PAD system might be configured at thresholds that are focused on minimizing APCER (or PA miss rate). We consider these ***security-focused*** use cases.

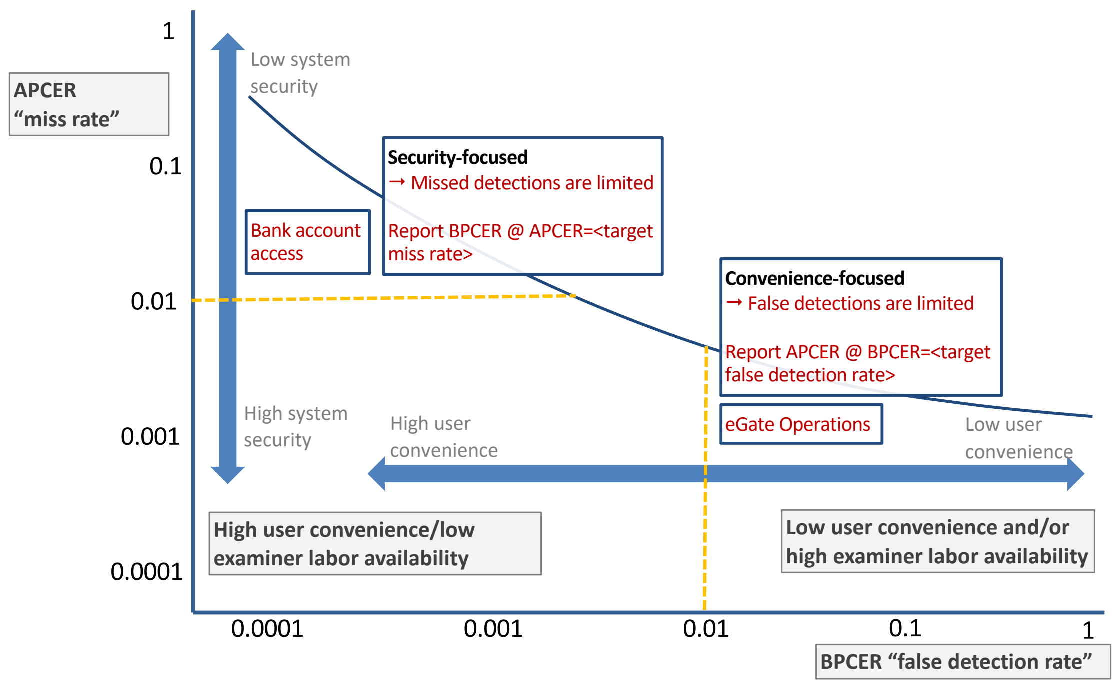



**Fig. 3.** Illustration of error tradeoff between misses and false detections.

There is typically a tradeoff between PA miss rates and false detection rates. Setting thresholds to minimize false detection rates will likely come at a cost of increased PA miss rates and vice versa. The results in this paper report the following:

- APCER @ BPCER = 0.01. Convenience-focused metric that reports the proportion of undetected PAs when the false detection rate is limited to 1% of bona fide imagery.
- BPCER @ APCER = 0.01. Security-focused metric that reports the proportion of bona fide images incorrectly flagged as PAs when the PA miss rate is limited to 1% of PA imagery.

## 4. Participation

The FATE PAD activity was open to participation worldwide between January 3rd, 2023 to February 28th, 2023. There was no charge to participate. Developers were allowed to submit up to two algorithms for evaluation. The process and format of algorithm submissions to NIST are described in the PAD Concept, Evaluation Plan, and API [6] document. Participants provided their submissions in the form of libraries compiled on a specific Linux kernel, which were linked against NIST's test harness to produce executables. NIST provided a validation package to participants to ensure that NIST's execution of submitted libraries produced the expected output on NIST's test machines.

This report documents the results of algorithms submitted to FATE PAD for testing, and Table 7 lists the algorithms that were tested, in alphabetical order.

**Table 7.** Participant Information. This table presents the participant location, organization name, algorithm name, and which PAD use cases were implemented.

| | Loc. | Developer Name | Short Name | Impersonation | Evasion |
|---|---|---|---|---|---|
| 1 | KR | Alchera Inc | alchera-000 | x | x |
| 2 | ES | Alice Biometrics | alice-000 | x | x |
| 3 | ES | Alice Biometrics | alice-001 | x | |
| 4 | US | Aware | aware-001 | x | x |
| 5 | US | Aware | aware-002 | x | x |
| 6 | IN | Biocube Matrics | biocube-001 | x | |
| 7 | IN | Biocube Matrics | biocube-002 | x | |
| 8 | KR | Cubox | cubox-000 | x | x |
| 9 | KR | Cubox | cubox-001 | x | x |
| 10 | TW | Cyberlink Corp | cyberlink-001 | x | x |
| 11 | TW | Cyberlink Corp | cyberlink-002 | x | x |
| 12 | US | Face Direct | facedirect-001 | x | x |
| 13 | US | Face Direct | facedirect-002 | x | x |
| 14 | ES | FacePhi | facephi-000 | x | |
| 15 | ES | FacePhi | facephi-001 | x | |
| 16 | US | Griaule | griaule-000 | x | x |
| 17 | US | Griaule | griaule-001 | x | x |
| 18 | MX | HuBOX | spooff-000 | x | x |
| 19 | IN | HyperVerge Inc | hyperverge-001 | x | |
| 20 | IN | HyperVerge Inc | hyperverge-002 | x | |
| 21 | US | ID R&D | idrnd-000 | x | |
| 22 | US | ID R&D | idrnd-001 | x | |
| 23 | CL | ID Vision Ctr | idvisioncenter-001 | x | |
| 24 | CL | ID Vision Ctr | idvisioncenter-002 | x | |
| 25 | FR | ID3 Technology | id3-001 | x | |
| 26 | FR | Idemia | idemia-010 | x | |
| 27 | FR | Idemia | idemia-011 | x | |
| 28 | SA | iiDENTIFii | iidentifii-000 | x | |
| 29 | US | Incode Technologies Inc | incode-000 | x | |
| 30 | US | Incode Technologies Inc | incode-001 | x | |
| 31 | SK | Innovatrics | innovatrics-001 | x | |
| 32 | SK | Innovatrics | innovatrics-002 | x | |
| 33 | LU | Intema-LGL Group | intema-000 | x | |
| 34 | LU | Intema-LGL Group | intema-001 | x | |
| 35 | UK | iProov | iproov-000 | x | |
| 36 | UK | iProov | iproov-001 | x | |
| 37 | JP | Japan Computer Vision | jcv-001 | x | x |
| 38 | JP | Japan Computer Vision | jcv-002 | x | |
| 39 | KR | Kakao Brain | kakao-000 | x | x |
| 40 | KR | Kakao Brain | kakao-001 | x | x |
| 41 | TH | Kasikorn Labs | kasikornlabs-000 | x | x |
| 42 | TH | Kasikorn Labs | kasikornlabs-001 | x | x |

**Table 7.** Participant Information. This table presents the participant location, organization name, algorithm name, and which PAD use cases were implemented. *(continued)*

| | Loc. | Developer Name | Short Name | Impersonation | Evasion |
|---|---|---|---|---|---|
| 43 | ES | Mobbeel Solutions | mobbl-000 | x | |
| 44 | ES | Mobbeel Solutions | mobbl-001 | x | |
| 45 | KZ | Modern Biometric Solutions | mbsolutions-000 | x | |
| 46 | KZ | Modern Biometric Solutions | mbsolutions-001 | x | |
| 47 | LT | Neurotechnology | neurotechnology-000 | x | x |
| 48 | LT | Neurotechnology | neurotechnology-001 | x | x |
| 49 | KR | NSENSE Korea | nsensekorea-000 | x | |
| 50 | KR | NSENSE Korea | nsensekorea-001 | x | |
| 51 | UK | Onfido | onfido-000 | x | x |
| 52 | UK | Onfido | onfido-001 | x | x |
| 53 | TW | PAPAGO Inc | papago-001 | x | x |
| 54 | CH | PXL Vision AG | pxl-000 | x | |
| 55 | CH | PXL Vision AG | pxl-001 | x | |
| 56 | US | Rank One Computing | rankone-000 | x | x |
| 57 | US | Rank One Computing | rankone-001 | x | x |
| 58 | DE | Saffe | saffe-001 | x | |
| 59 | DE | Saffe | saffe-002 | x | |
| 60 | SA | STCON LLC | stcon-000 | x | |
| 61 | SA | STCON LLC | stcon-001 | x | |
| 62 | CH | Tech5 SA | tech5-001 | x | |
| 63 | TR | Techsign | techsign-000 | x | |
| 64 | TR | Techsign | techsign-001 | x | |
| 65 | US | Trueface.ai | trueface-000 | x | x |
| 66 | PT | Universidade de Coimbra | visteam-001 | x | |
| 67 | PT | Universidade de Coimbra | visteam-002 | x | |
| 68 | TW | UXLabs | uxlabs-001 | x | x |
| 69 | ES | Veridas Digital Authentication Sol. | veridas-001 | x | |
| 70 | ES | Veridas Digital Authentication Sol. | veridas-002 | x | |
| 71 | KZ | Verigram | verigram-000 | x | |
| 72 | KZ | Verigram | verigram-001 | x | |
| 73 | ID | Verihubs | verihubs-inteligensia-000 | x | |
| 74 | ID | Verihubs | verihubs-inteligensia-001 | x | |
| 75 | ID | VIDA-Digital Identity Pte Ltd | vida-001 | x | |
| 76 | ID | VIDA-Digital Identity Pte Ltd | vida-002 | x | |
| 77 | CN | Vision Intelligence Ctr of Meituan | meituan-000 | x | |
| 78 | CN | Vision Intelligence Ctr of Meituan | meituan-001 | x | |
| 79 | PT | YooniK | yoonik-001 | x | |
| 80 | PT | YooniK | yoonik-002 | x | |
| 81 | UK | Yoti | yoti-001 | x | |
| 82 | UK | Yoti | yoti-002 | x | |

## 5. Results

The results in this section summarize PAD performance for the top performing algorithms. A complete tabulation of performance results for all algorithms is documented in Appendix A. The number after the ± indicates uncertainty related to sample size - it spans 95% of bootstrap samples of the PA scores.

### 5.1. Impersonation

**Table 8.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-001 | 0.07 ± 0.01 | 1 | iproov-000 | 0.069 | 1 |
| idrnd-001 | 0.1 ± 0.02 | 2 | idrnd-001 | 0.082 | 2 |
| idrnd-000 | 0.12 ± 0.02 | 3 | kakao-001 | 0.105 | 3 |
| stcon-001 | 0.13 ± 0.02 | 4 | idrnd-000 | 0.133 | 4 |
| iproov-001 | 0.16 ± 0.02 | 5 | cyberlink-002 | 0.207 | 5 |
| cyberlink-002 | 0.18 ± 0.02 | 6 | aware-001 | 0.308 | 6 |
| kakao-000 | 0.31 ± 0.03 | 7 | stcon-001 | 0.346 | 7 |
| stcon-000 | 0.31 ± 0.03 | 7 | kasikornlabs-000 | 0.348 | 8 |
| cyberlink-001 | 0.42 ± 0.03 | 9 | aware-002 | 0.356 | 9 |
| onfido-000 | 0.47 ± 0.03 | 10 | iproov-001 | 0.377 | 10 |

**Table 9.** PA Type 3 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| stcon-001 | 0 ± 0 | 1 | stcon-001 | 0.000 | 1 |
| stcon-000 | 0.005 ± 0.007 | 2 | alice-001 | 0.004 | 2 |
| alice-001 | 0.01 ± 0.01 | 3 | stcon-000 | 0.006 | 3 |
| cyberlink-002 | 0.01 ± 0.01 | 3 | cyberlink-002 | 0.007 | 4 |
| idrnd-001 | 0.02 ± 0.02 | 5 | idrnd-001 | 0.012 | 5 |
| incode-001 | 0.02 ± 0.02 | 5 | alice-000 | 0.014 | 6 |
| idrnd-000 | 0.03 ± 0.02 | 7 | cyberlink-001 | 0.020 | 7 |
| cyberlink-001 | 0.03 ± 0.02 | 7 | iproov-000 | 0.021 | 8 |
| onfido-000 | 0.05 ± 0.03 | 9 | idrnd-000 | 0.027 | 9 |
| iidentifii-000 | 0.06 ± 0.03 | 10 | onfido-000 | 0.036 | 10 |

**Table 10.** PA Type 4 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| cyberlink-002 | 0.13 ± 0.03 | 1 | aware-001 | 0.200 | 1 |
| cyberlink-001 | 0.18 ± 0.03 | 2 | cyberlink-002 | 0.207 | 2 |
| stcon-001 | 0.19 ± 0.03 | 3 | iproov-000 | 0.315 | 3 |
| stcon-000 | 0.29 ± 0.04 | 4 | aware-002 | 0.322 | 4 |
| idrnd-001 | 0.42 ± 0.04 | 5 | idrnd-001 | 0.395 | 5 |
| idrnd-000 | 0.47 ± 0.04 | 6 | idrnd-000 | 0.395 | 5 |
| meituan-001 | 0.53 ± 0.04 | 7 | cyberlink-001 | 0.408 | 7 |
| iproov-001 | 0.55 ± 0.04 | 8 | vida-001 | 0.447 | 8 |
| alice-001 | 0.56 ± 0.04 | 9 | kasikornlabs-000 | 0.452 | 9 |
| jcv-001 | 0.59 ± 0.04 | 10 | intema-001 | 0.463 | 10 |

**Table 11.** PA Type 7 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| cyberlink-002 | 0.012 ± 0.003 | 1 | cyberlink-002 | 0.012 | 1 |
| cyberlink-001 | 0.052 ± 0.006 | 2 | cyberlink-001 | 0.095 | 2 |
| kakao-001 | 0.06 ± 0.007 | 3 | kakao-001 | 0.159 | 3 |
| alice-001 | 0.108 ± 0.009 | 4 | onfido-001 | 0.263 | 4 |
| kakao-000 | 0.16 ± 0.01 | 5 | innovatrics-002 | 0.275 | 5 |
| hyperverge-002 | 0.31 ± 0.01 | 6 | veridas-002 | 0.291 | 6 |
| veridas-002 | 0.32 ± 0.01 | 7 | veridas-001 | 0.297 | 7 |
| onfido-001 | 0.33 ± 0.01 | 8 | alice-001 | 0.345 | 8 |
| idrnd-000 | 0.33 ± 0.01 | 8 | idrnd-000 | 0.348 | 9 |
| idrnd-001 | 0.42 ± 0.01 | 10 | idrnd-001 | 0.356 | 10 |

**Table 12.** PA Type 8 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| alice-001 | 0 ± 0 | 1 | alice-001 | 0.000 | 1 |
| idemia-011 | 0 ± 0 | 1 | idrnd-000 | 0.000 | 1 |
| idrnd-000 | 0 ± 0 | 1 | idrnd-001 | 0.000 | 1 |
| idrnd-001 | 0 ± 0 | 1 | idemia-011 | 0.002 | 4 |
| hyperverge-002 | 0.001 ± 0.001 | 5 | hyperverge-002 | 0.003 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| kakao-001 | 0.001 ± 0.001 | 5 | kakao-001 | 0.003 | 5 |
| iproov-001 | 0.003 ± 0.002 | 7 | meituan-001 | 0.003 | 5 |
| meituan-001 | 0.004 ± 0.003 | 8 | iproov-001 | 0.005 | 8 |
| stcon-000 | 0.008 ± 0.005 | 9 | kakao-000 | 0.005 | 8 |
| hyperverge-001 | 0.008 ± 0.005 | 9 | stcon-000 | 0.007 | 10 |

**Table 13.** PA Type 8 (zoomed) - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| idrnd-001 | 0.005 ± 0.004 | 1 | idrnd-001 | 0.006 | 1 |
| idrnd-000 | 0.011 ± 0.005 | 2 | idrnd-000 | 0.010 | 2 |
| stcon-000 | 0.018 ± 0.007 | 3 | stcon-000 | 0.016 | 3 |
| idemia-011 | 0.028 ± 0.009 | 4 | idemia-011 | 0.026 | 4 |
| kakao-001 | 0.031 ± 0.009 | 5 | kakao-001 | 0.026 | 4 |
| iproov-001 | 0.04 ± 0.01 | 6 | jcv-002 | 0.039 | 6 |
| jcv-001 | 0.05 ± 0.01 | 7 | jcv-001 | 0.044 | 7 |
| stcon-001 | 0.06 ± 0.01 | 8 | meituan-001 | 0.045 | 8 |
| onfido-001 | 0.06 ± 0.01 | 8 | iproov-000 | 0.046 | 9 |
| kakao-000 | 0.06 ± 0.01 | 8 | iproov-001 | 0.047 | 10 |

## 5.2. Evasion

**Table 14.** PA Type 1 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-001 | 0.13 ± 0.01 | 1 | kakao-001 | 0.151 | 1 |
| kakao-000 | 0.28 ± 0.02 | 2 | cyberlink-002 | 0.254 | 2 |
| rankone-000 | 0.39 ± 0.02 | 3 | aware-002 | 0.418 | 3 |
| rankone-001 | 0.39 ± 0.02 | 3 | kasikornlabs-000 | 0.495 | 4 |
| kasikornlabs-000 | 0.4 ± 0.02 | 5 | aware-001 | 0.507 | 5 |
| cyberlink-002 | 0.44 ± 0.02 | 6 | alice-000 | 0.517 | 6 |
| aware-002 | 0.51 ± 0.02 | 7 | kasikornlabs-001 | 0.542 | 7 |
| neurotechnology-000 | 0.53 ± 0.02 | 8 | uxlabs-001 | 0.600 | 8 |
| kasikornlabs-001 | 0.53 ± 0.02 | 8 | kakao-000 | 0.635 | 9 |
| onfido-000 | 0.55 ± 0.02 | 10 | rankone-000 | 0.665 | 10 |

**Table 15.** PA Type 2 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-001 | 0.12 ± 0.06 | 1 | alice-000 | 0.035 | 1 |
| onfido-000 | 0.17 ± 0.07 | 2 | cyberlink-002 | 0.077 | 2 |
| kakao-000 | 0.18 ± 0.07 | 3 | kakao-001 | 0.108 | 3 |
| aware-002 | 0.33 ± 0.09 | 4 | aware-001 | 0.171 | 4 |
| onfido-001 | 0.4 ± 0.1 | 5 | aware-002 | 0.173 | 5 |
| neurotechnology-000 | 0.4 ± 0.1 | 5 | onfido-000 | 0.221 | 6 |
| cyberlink-002 | 0.4 ± 0.1 | 5 | neurotechnology-000 | 0.297 | 7 |
| kasikornlabs-000 | 0.5 ± 0.1 | 8 | kakao-000 | 0.315 | 8 |
| kasikornlabs-001 | 0.6 ± 0.1 | 9 | cyberlink-001 | 0.361 | 9 |
| facedirect-002 | 0.64 ± 0.09 | 10 | kasikornlabs-001 | 0.386 | 10 |

**Table 16.** PA Type 3 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| onfido-000 | 0.05 ± 0.03 | 1 | alice-000 | 0.014 | 1 |
| onfido-001 | 0.09 ± 0.04 | 2 | onfido-000 | 0.036 | 2 |
| aware-002 | 0.1 ± 0.04 | 3 | cyberlink-002 | 0.041 | 3 |
| facedirect-002 | 0.16 ± 0.05 | 4 | onfido-001 | 0.051 | 4 |
| neurotechnology-000 | 0.26 ± 0.06 | 5 | aware-001 | 0.052 | 5 |
| kasikornlabs-000 | 0.26 ± 0.06 | 5 | aware-002 | 0.057 | 6 |
| kasikornlabs-001 | 0.29 ± 0.06 | 7 | neurotechnology-000 | 0.197 | 7 |
| kakao-001 | 0.57 ± 0.07 | 8 | kasikornlabs-000 | 0.251 | 8 |
| cyberlink-002 | 0.6 ± 0.07 | 9 | neurotechnology-001 | 0.297 | 9 |
| kakao-000 | 0.68 ± 0.06 | 10 | kasikornlabs-001 | 0.329 | 10 |

**Table 17.** PA Type 4 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kasikornlabs-000 | 0.62 ± 0.04 | 1 | aware-001 | 0.191 | 1 |
| kasikornlabs-001 | 0.62 ± 0.04 | 1 | aware-002 | 0.348 | 2 |
| cyberlink-002 | 0.63 ± 0.04 | 3 | cyberlink-002 | 0.446 | 3 |
| onfido-001 | 0.74 ± 0.03 | 4 | kasikornlabs-000 | 0.452 | 4 |
| aware-002 | 0.76 ± 0.03 | 5 | kasikornlabs-001 | 0.555 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| kakao-001 | 0.82 ± 0.03 | 6 | onfido-001 | 0.621 | 6 |
| onfido-000 | 0.82 ± 0.03 | 6 | onfido-000 | 0.788 | 7 |
| kakao-000 | 0.89 ± 0.03 | 8 | alice-000 | 0.813 | 8 |
| facedirect-001 | 0.9 ± 0.02 | 9 | kakao-001 | 0.815 | 9 |
| cubox-001 | 0.9 ± 0.02 | 9 | neurotechnology-001 | 0.883 | 10 |

**Table 18.** PA Type 5 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-001 | 0 ± 0 | 1 | kakao-001 | 0.001 | 1 |
| kakao-000 | 0.02 ± 0.01 | 2 | kakao-000 | 0.034 | 2 |
| cyberlink-002 | 0.34 ± 0.06 | 3 | uxlabs-001 | 0.207 | 3 |
| facedirect-002 | 0.44 ± 0.06 | 4 | aware-002 | 0.390 | 4 |
| aware-002 | 0.65 ± 0.06 | 5 | aware-001 | 0.495 | 5 |
| griaule-000 | 0.68 ± 0.06 | 6 | spooff-000 | 0.497 | 6 |
| rankone-000 | 0.73 ± 0.05 | 7 | cyberlink-002 | 0.560 | 7 |
| rankone-001 | 0.73 ± 0.05 | 7 | rankone-000 | 0.665 | 8 |
| onfido-001 | 0.79 ± 0.05 | 9 | rankone-001 | 0.665 | 8 |
| onfido-000 | 0.82 ± 0.04 | 10 | papago-001 | 0.696 | 10 |

**Table 19.** PA Type 6 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| rankone-000 | 0 ± 0 | 1 | rankone-000 | 0.000 | 1 |
| rankone-001 | 0 ± 0 | 1 | rankone-001 | 0.000 | 1 |
| trueface-000 | 0.002 ± 0.002 | 3 | trueface-000 | 0.003 | 3 |
| kakao-000 | 0.008 ± 0.005 | 4 | kakao-000 | 0.004 | 4 |
| cyberlink-002 | 0.012 ± 0.006 | 5 | cyberlink-002 | 0.011 | 5 |
| kakao-001 | 0.014 ± 0.007 | 6 | kakao-001 | 0.012 | 6 |
| neurotechnology-000 | 0.21 ± 0.02 | 7 | aware-001 | 0.038 | 7 |
| griaule-001 | 0.34 ± 0.03 | 8 | aware-002 | 0.053 | 8 |
| griaule-000 | 0.49 ± 0.03 | 9 | cyberlink-001 | 0.119 | 9 |
| aware-002 | 0.51 ± 0.03 | 10 | uxlabs-001 | 0.133 | 10 |

**Table 20.** PA Type 7 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-001 | 0.14 ± 0.01 | 1 | cyberlink-002 | 0.035 | 1 |
| kakao-000 | 0.15 ± 0.01 | 2 | kakao-001 | 0.202 | 2 |
| onfido-001 | 0.34 ± 0.01 | 3 | onfido-001 | 0.284 | 3 |
| onfido-000 | 0.43 ± 0.01 | 4 | alice-000 | 0.377 | 4 |
| rankone-000 | 0.52 ± 0.01 | 5 | aware-002 | 0.473 | 5 |
| rankone-001 | 0.52 ± 0.01 | 5 | uxlabs-001 | 0.495 | 6 |
| cyberlink-002 | 0.52 ± 0.01 | 5 | neurotechnology-000 | 0.525 | 7 |
| neurotechnology-000 | 0.65 ± 0.01 | 8 | kakao-000 | 0.574 | 8 |
| aware-002 | 0.8 ± 0.01 | 9 | rankone-000 | 0.607 | 9 |
| kasikornlabs-000 | 0.84 ± 0.01 | 10 | rankone-001 | 0.607 | 9 |

**Table 21.** PA Type 8 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kakao-000 | 0.009 ± 0.005 | 1 | kakao-000 | 0.006 | 1 |
| onfido-001 | 0.017 ± 0.007 | 2 | kakao-001 | 0.013 | 2 |
| kakao-001 | 0.018 ± 0.007 | 3 | alice-000 | 0.015 | 3 |
| onfido-000 | 0.024 ± 0.008 | 4 | onfido-000 | 0.019 | 4 |
| aware-002 | 0.08 ± 0.01 | 5 | onfido-001 | 0.020 | 5 |
| kasikornlabs-000 | 0.09 ± 0.01 | 6 | cyberlink-002 | 0.067 | 6 |
| neurotechnology-000 | 0.1 ± 0.02 | 7 | aware-002 | 0.075 | 7 |
| kasikornlabs-001 | 0.15 ± 0.02 | 8 | neurotechnology-000 | 0.095 | 8 |
| facedirect-002 | 0.47 ± 0.03 | 9 | kasikornlabs-000 | 0.126 | 9 |
| cyberlink-002 | 0.51 ± 0.03 | 10 | kasikornlabs-001 | 0.141 | 10 |

**Table 22.** PA Type 8 (zoomed) - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| onfido-001 | 0.06 ± 0.01 | 1 | kakao-001 | 0.052 | 1 |
| onfido-000 | 0.07 ± 0.01 | 2 | onfido-001 | 0.096 | 2 |
| kakao-000 | 0.07 ± 0.01 | 2 | kakao-000 | 0.099 | 3 |
| kakao-001 | 0.12 ± 0.02 | 4 | onfido-000 | 0.219 | 4 |
| kasikornlabs-000 | 0.12 ± 0.02 | 4 | neurotechnology-001 | 0.224 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| kasikornlabs-001 | 0.22 ± 0.02 | 6 | aware-002 | 0.329 | 6 |
| facedirect-002 | 0.3 ± 0.02 | 7 | kasikornlabs-000 | 0.574 | 7 |
| neurotechnology-000 | 0.3 ± 0.02 | 7 | kasikornlabs-001 | 0.628 | 8 |
| aware-002 | 0.31 ± 0.02 | 9 | uxlabs-001 | 0.628 | 8 |
| facedirect-001 | 0.83 ± 0.02 | 10 | papago-001 | 0.696 | 10 |

**Table 23.** PA Type 9 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | (Convenience) APCER @ BPCER=0.01 | Rank | Algorithm | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|
| kasikornlabs-000 | 0.052 ± 0.005 | 1 | cyberlink-002 | 0.027 | 1 |
| kasikornlabs-001 | 0.063 ± 0.006 | 2 | alice-000 | 0.034 | 2 |
| onfido-000 | 0.068 ± 0.006 | 3 | kasikornlabs-000 | 0.055 | 3 |
| kakao-001 | 0.107 ± 0.007 | 4 | aware-001 | 0.066 | 4 |
| onfido-001 | 0.135 ± 0.008 | 5 | kasikornlabs-001 | 0.095 | 5 |
| kakao-000 | 0.25 ± 0.01 | 6 | onfido-000 | 0.146 | 6 |
| rankone-000 | 0.27 ± 0.01 | 7 | aware-002 | 0.161 | 7 |
| rankone-001 | 0.27 ± 0.01 | 7 | onfido-001 | 0.195 | 8 |
| aware-002 | 0.34 ± 0.01 | 9 | uxlabs-001 | 0.200 | 9 |
| cyberlink-002 | 0.41 ± 0.01 | 10 | kakao-001 | 0.242 | 10 |

## 5.3. Stills vs. Videos

The evaluation dataset contained 747 videos (538 bona fide, 209 PA). For each video collected, there was also a corresponding still image captured from the same collection event. This allows for the comparison of PAD performance when the input media is a video sequence or a single still image.

### 5.3.1. Impersonation

There were a total of 538 bona fide videos and corresponding stills and 79 impersonation PA videos and corresponding stills across 3 different PA types. DET analysis was conducted using all 79 PA imagery collections and 538 bona fide imagery collections. Table 24 tabulates performance results by still vs. video imagery. Individual PAD performance with videos for each PA type is available in Appendix A.2.

**Table 24.** Use Case: detectImpersonationPA - Stills vs. Videos

| | (Convenience) APCER @ BPCER=0.01 | (Security) BPCER @ APCER=0.01 |
|---|---|---|

| Algorithm | Stills | Videos | Algorithm | Stills | Videos |
|---|---|---|---|---|---|
| cyberlink-002 | 0.00 | 0.00 | cyberlink-002 | 0.00 | 0.01 |
| stcon-001 | 0.03 | 0.01 | stcon-001 | 0.05 | 0.01 |
| cyberlink-001 | 0.03 | 0.03 | kasikornlabs-000 | 0.19 | 0.02 |
| idrnd-001 | 0.05 | 0.03 | cyberlink-001 | 0.03 | 0.03 |
| iproov-001 | 0.05 | 0.03 | iproov-000 | 0.05 | 0.03 |
| stcon-000 | 0.09 | 0.03 | idrnd-001 | 0.07 | 0.03 |
| idrnd-000 | 0.08 | 0.04 | kakao-001 | 0.07 | 0.05 |
| kakao-001 | 0.01 | 0.04 | kasikornlabs-001 | 0.25 | 0.06 |
| kasikornlabs-000 | 0.10 | 0.04 | hyperverge-002 | 1.00 | 0.07 |
| alice-001 | 0.12 | 0.06 | iproov-001 | 0.05 | 0.07 |

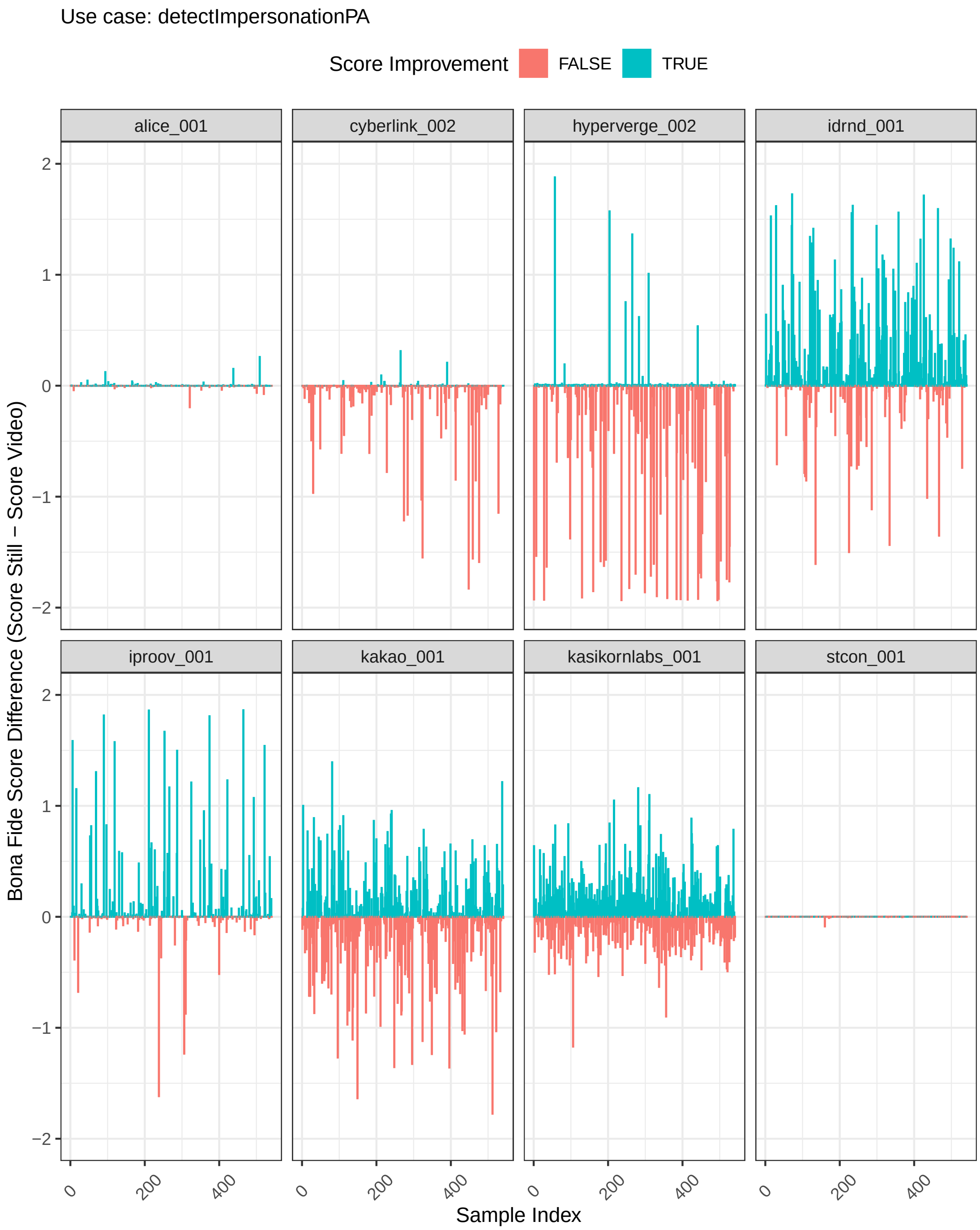



**Fig. 4.** This plot presents 1) pairwise bona fide PAD score differences between still and video scores of the same collection event and 2) whether or not a video sequence of the same collection event yields improvements over a single still image for better bona fide prediction outcomes. Teal colored lines represent improvement in bona fide PAD scores when a video is provided as input (vs. a still image), and the length of the line represents the magnitude of improvement (longer lines mean more improvement). Red lines indicate degradation of bona fide PAD scores with video input (vs. still), which means bona fide prediction degrades when the input is a video when compared to a still image.

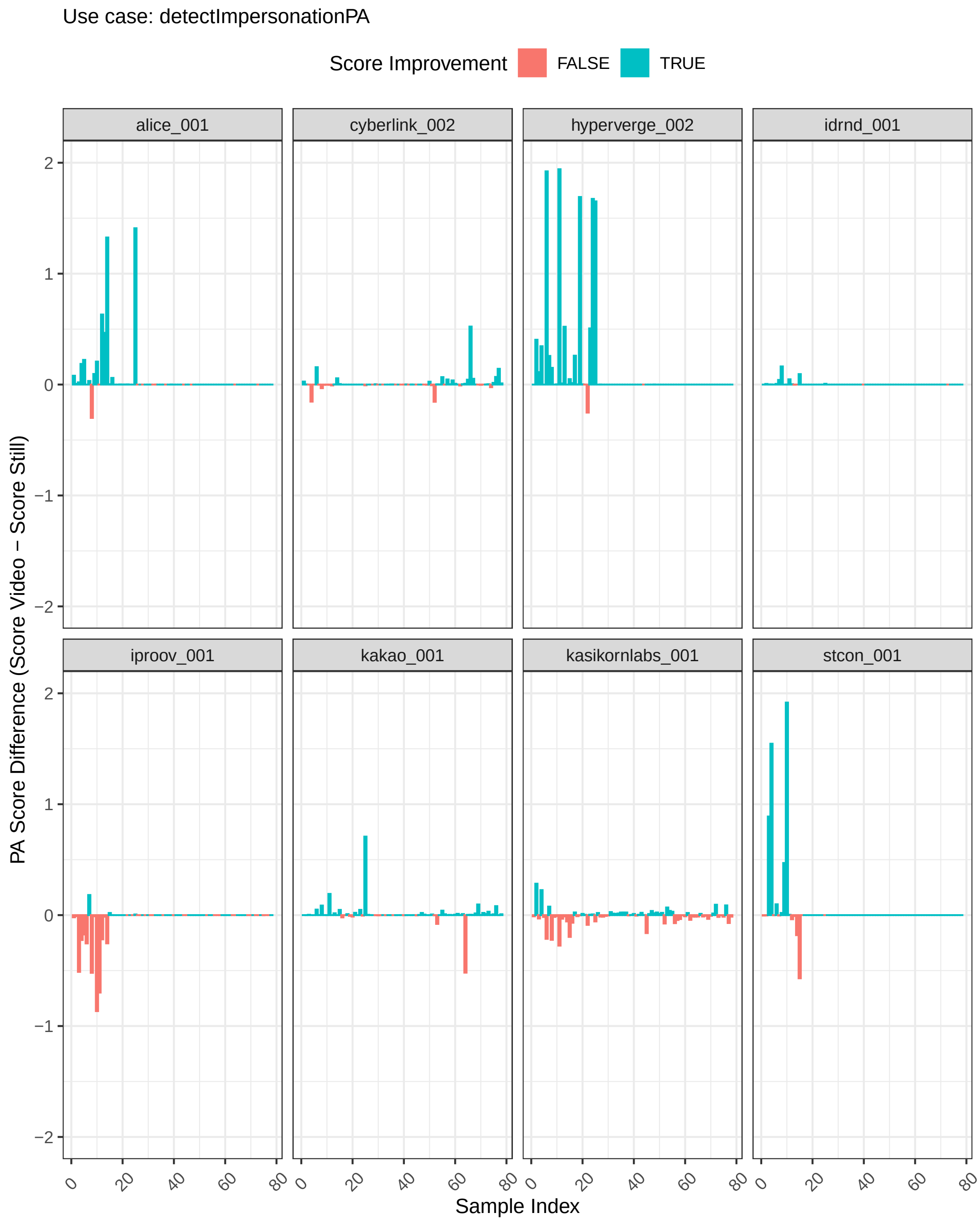



**Fig. 5.** This plot presents 1) pairwise PA PAD score differences between still and video scores of the same collection event and 2) whether or not a video sequence of the same collection event yields improvements over a single still image for better PA prediction outcomes. Teal colored lines represent improvement in PA PAD scores when a video is provided as input (vs. a still image), and the length of the line represents the magnitude of improvement (longer lines mean more improvement). Red lines indicate degradation of PA PAD scores with video input (vs. still), which means PA prediction degrades when the input is a video when compared to a still image.

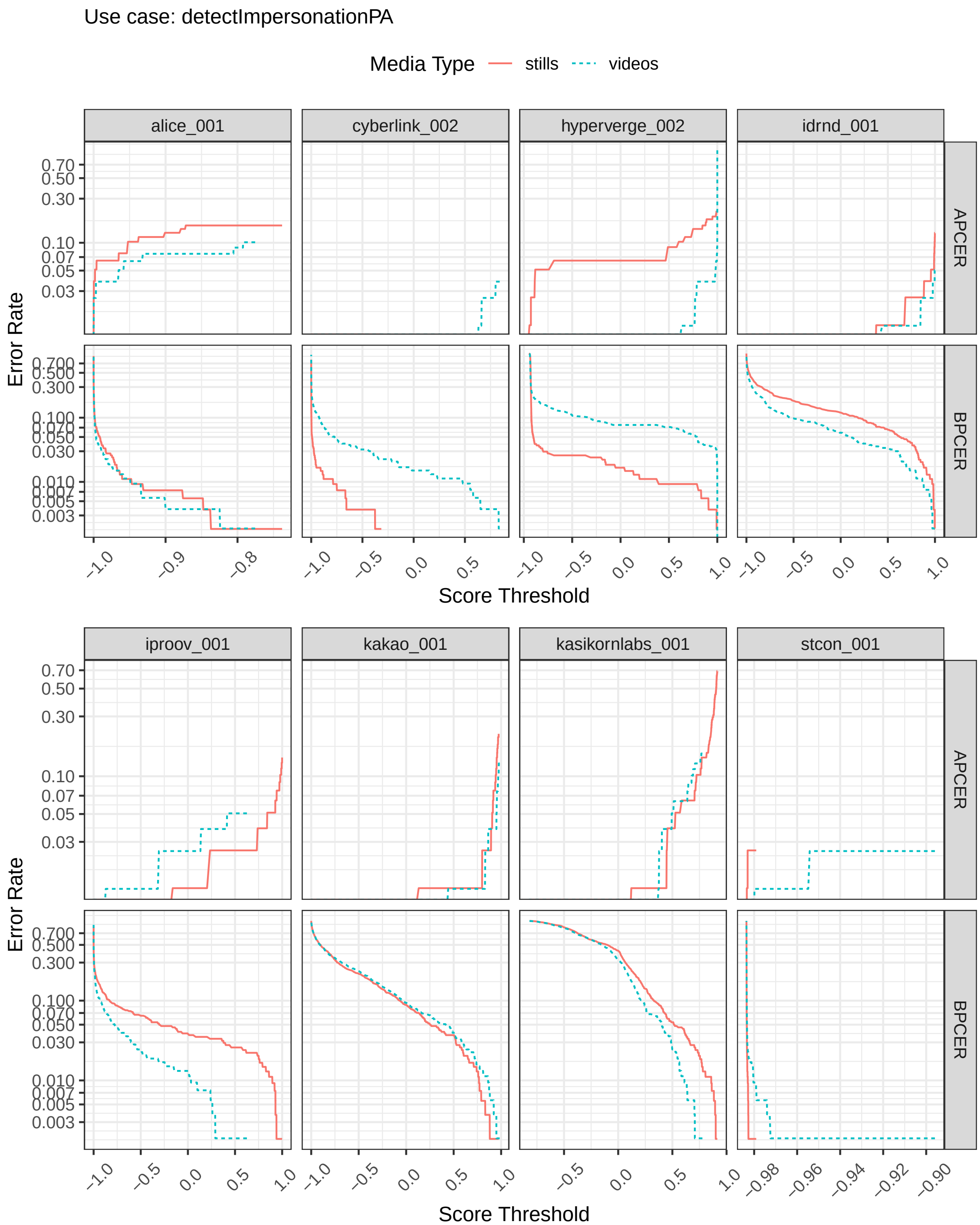



**Fig. 6.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

### 5.3.2. Evasion

There were a total of 538 bona fide videos and corresponding stills and 209 evasion PA videos and corresponding stills across 5 different PA types. DET analysis was conducted using all 209 PA imagery collections and 538 bona fide imagery collections. Table 25 tabulates performance results by still vs. video imagery. Individual PAD performance with videos for each PA type is available in Appendix A.3.

**Table 25.** Use Case: detectEvasionPA - Stills vs. Videos

| | (Convenience) APCER @ BPCER=0.01 | | | (Security) BPCER @ APCER=0.01 | |
|---|---|---|---|---|---|
| Algorithm | Stills | Videos | Algorithm | Stills | Videos |
| kakao-001 | 0.11 | 0.04 | kakao-001 | 0.11 | 0.03 |
| kakao-000 | 0.25 | 0.19 | kakao-000 | 0.16 | 0.17 |
| kasikornlabs-000 | 0.38 | 0.32 | cyberlink-002 | 0.24 | 0.28 |
| kasikornlabs-001 | 0.47 | 0.36 | uxlabs-001 | 0.48 | 0.51 |
| onfido-000 | 0.36 | 0.38 | aware-001 | 0.49 | 0.57 |
| neurotechnology-000 | 0.37 | 0.44 | neurotechnology-000 | 1.00 | 0.57 |
| onfido-001 | 0.53 | 0.49 | alice-000 | 0.49 | 0.62 |
| cyberlink-002 | 0.75 | 0.52 | onfido-001 | 0.77 | 0.71 |
| facedirect-002 | 0.83 | 0.72 | aware-002 | 0.51 | 0.72 |
| aware-002 | 0.68 | 0.81 | onfido-000 | 0.74 | 0.81 |

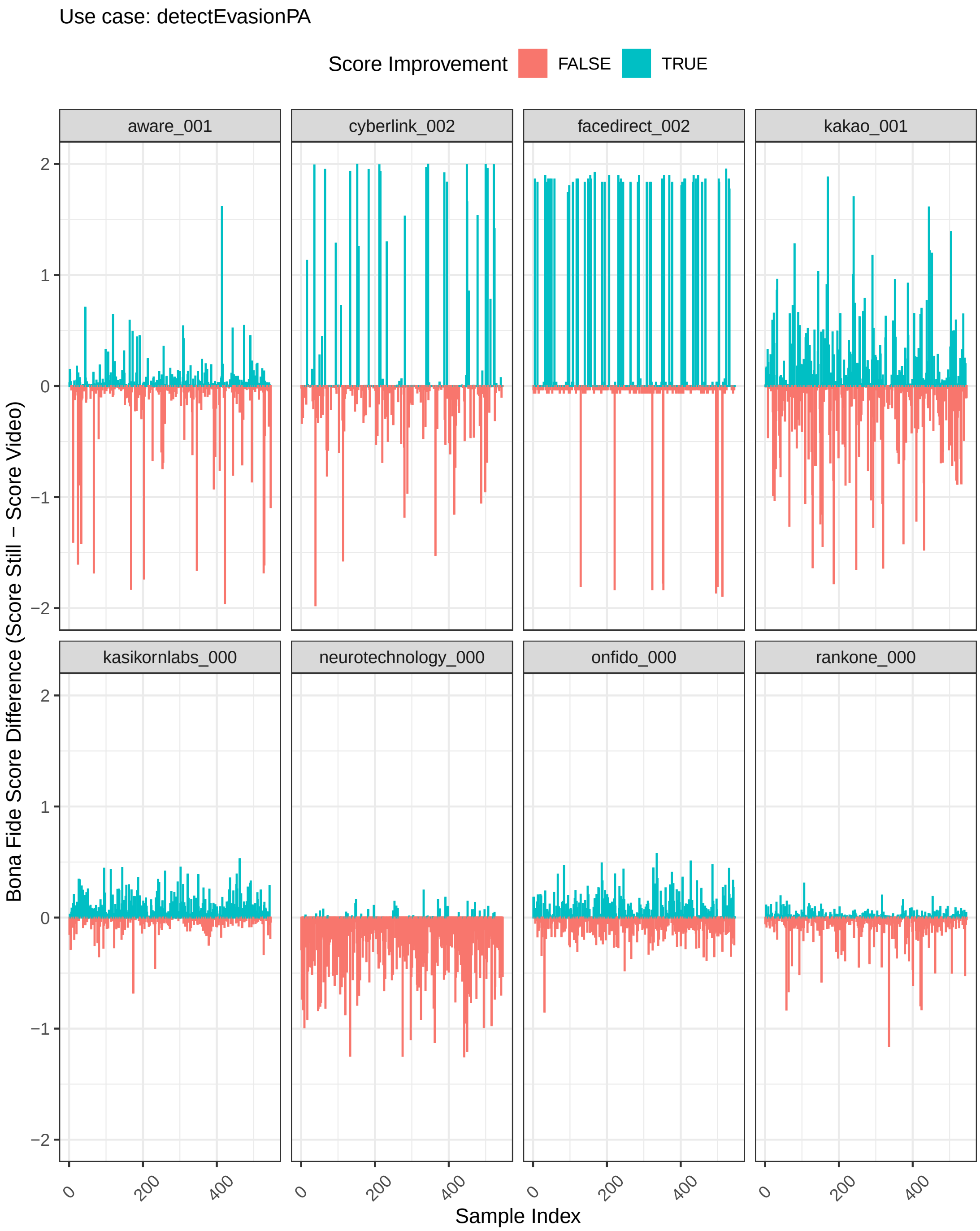



**Fig. 7.** This plot presents 1) pairwise bona fide PAD score differences between still and video scores of the same collection event and 2) whether or not a video sequence of the same collection event yields improvements over a single still image for better bona fide prediction outcomes. Teal colored lines represent improvement in bona fide PAD scores when a video is provided as input (vs. a still image), and the length of the line represents the magnitude of improvement (longer lines mean more improvement). Red lines indicate degradation of bona fide PAD scores with video input (vs. still), which means bona fide prediction degrades when the input is a video when compared to a still image.

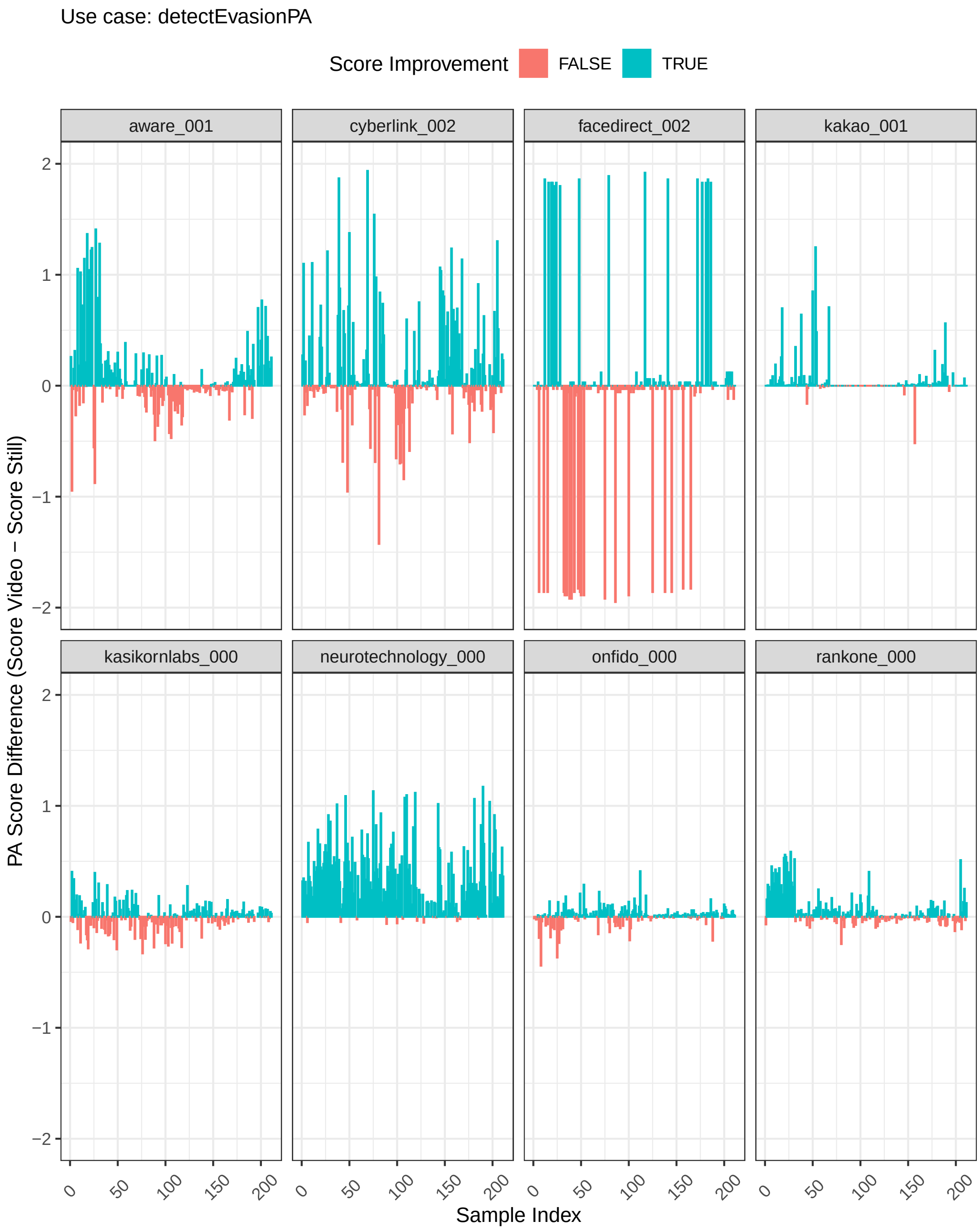



**Fig. 8.** This plot presents 1) pairwise PA PAD score differences between still and video scores of the same collection event and 2) whether or not a video sequence of the same collection event yields improvements over a single still image for better PA prediction outcomes. Teal colored lines represent improvement in PA PAD scores when a video is provided as input (vs. a still image), and the length of the line represents the magnitude of improvement (longer lines mean more improvement). Red lines indicate degradation of PA PAD scores with video input (vs. still), which means PA prediction degrades when the input is a video when compared to a still image.

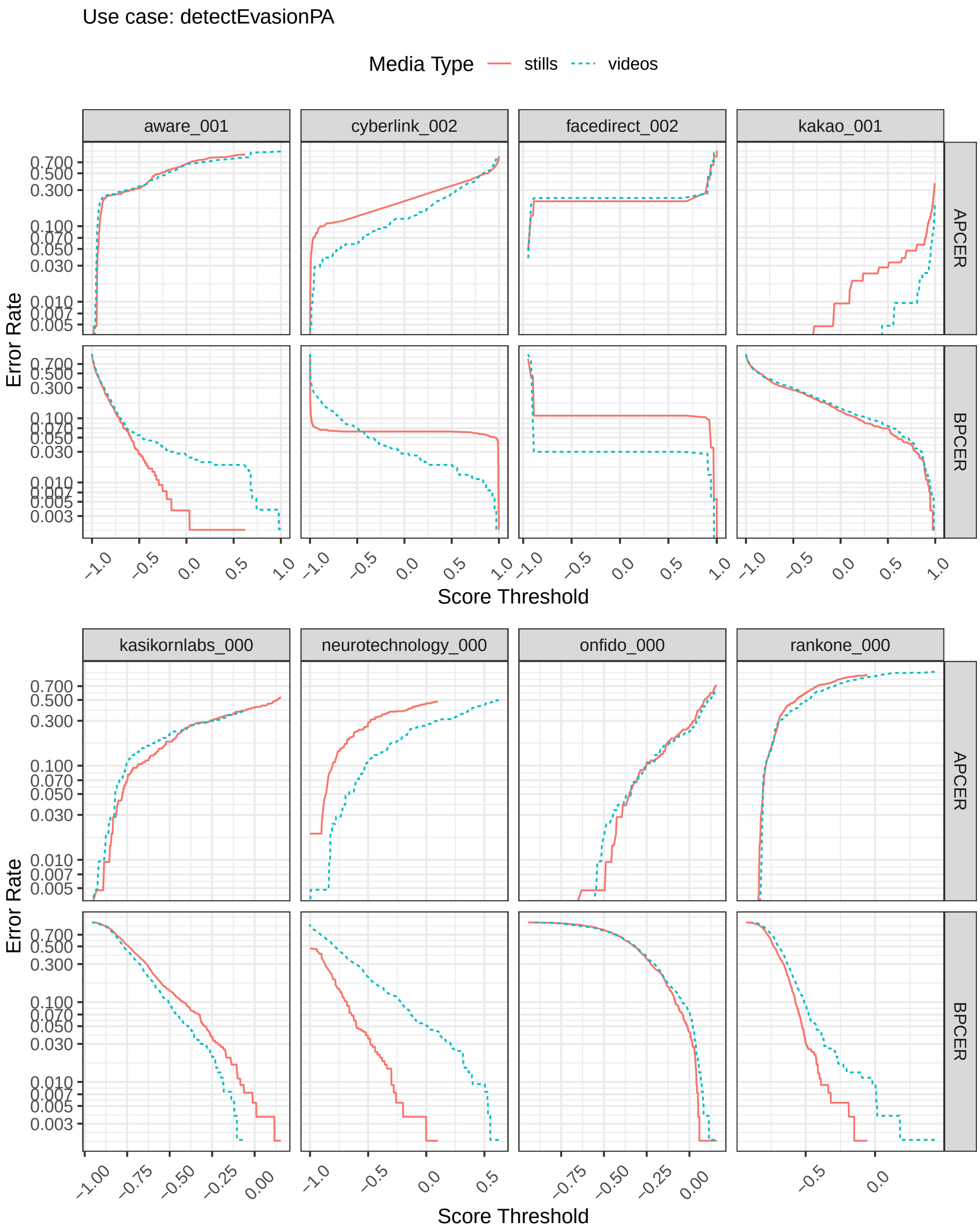



**Fig. 9.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

### 5.4. Fusion

Biometric systems utilize the concept of fusion to combine information from multiple sources to try and improve recognition accuracy. Here, we investigate whether and to what extent fusion of multiple PAD algorithms might improve detection outcomes. While there is a plethora of fusion schemes that exist, as a proof of concept, we perform fusion across multiple PAD algorithms by simply fusing the scores using the sum rule. That is, given N algorithms, $\text{score}_{\text{fused}} = \sum_{alg=1}^{N} \text{score}_{\text{alg}}$. Tables 26 and 27 summarize the results of fusion for each detection task and PA type, with the fused performance ranking relative to all algorithms tested. For each use case, the algorithms selected for fusion were broadly top performing algorithms in one or more PA categories.

#### 5.4.1. Impersonation

The results in Table 26 were generated by fusing four algorithms: cyberlink-002, idrnd-001, kakao-001, and stcon-001.

**Table 26.** Fusion Results - Use Case: detectImpersonationPA - Media Type: stills

| PA Description | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|
| PA Type 1 | 0.004 ± 0.004 | 1 | 0.004 | 1 |
| PA Type 3 | 0 ± 0 | 1 | 0.000 | 1 |
| PA Type 4 | 0.1 ± 0.02 | 1 | 0.159 | 1 |
| PA Type 7 | 0.006 ± 0.002 | 1 | 0.005 | 1 |
| PA Type 8 | 0 ± 0 | 1 | 0.000 | 1 |
| PA Type 8 (zoomed) | 0 ± 0 | 1 | 0.003 | 1 |

#### 5.4.2. Evasion

The results in Table 27 were generated by fusing four algorithms: aware-001, cyberlink-002, kakao-001, and onfido-000.

**Table 27.** Fusion Results - Use Case: detectEvasionPA - Media Type: stills

| PA Description | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|
| PA Type 1 | 0.062 ± 0.008 | 1 | 0.088 | 1 |
| PA Type 2 | 0.01 ± 0.01 | 1 | 0.009 | 1 |
| PA Type 3 | 0.01 ± 0.01 | 1 | 0.006 | 1 |
| PA Type 4 | 0.26 ± 0.03 | 1 | 0.193 | 2 |

| | | | | |
|---|---|---|---|---|
| PA Type 5 | 0.04 ± 0.03 | 3 | 0.023 | 2 |
| PA Type 6 | 0 ± 0 | 1 | 0.000 | 3 |
| PA Type 7 | 0.017 ± 0.004 | 1 | 0.023 | 1 |
| PA Type 8 | 0.001 ± 0.001 | 1 | 0.006 | 1 |
| PA Type 8 (zoomed) | 0.15 ± 0.02 | 6 | 0.080 | 2 |
| PA Type 9 | 0.003 ± 0.001 | 1 | 0.004 | 1 |

## 5.5. Demographic Effects

While demographic effects was not a primary evaluation objective, first-order analysis of results broken out by demographic groups may nevertheless be useful to developers. Initially, we assess BPCER/false detection rates across the different demographic groups represented in the test data. Tables 10 and 11 plot BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White-Male. While there is imbalance in the number of photos in each group, the error rate stands as the best estimate of false detection predictions for each group. While the BPCER for the smallest group may yield higher levels of uncertainty, we expect the level of uncertainty to remain small given the number of images processed.

**Table 28.** Demographic Data Summary, Bona Fide Stills

| Demographic | Count |
|---|---|
| White-Male | 5866 |
| White-Female | 9265 |
| Black-Male | 1119 |
| Black-Female | 2464 |
| Asian-Male | 665 |
| Asian-Female | 735 |

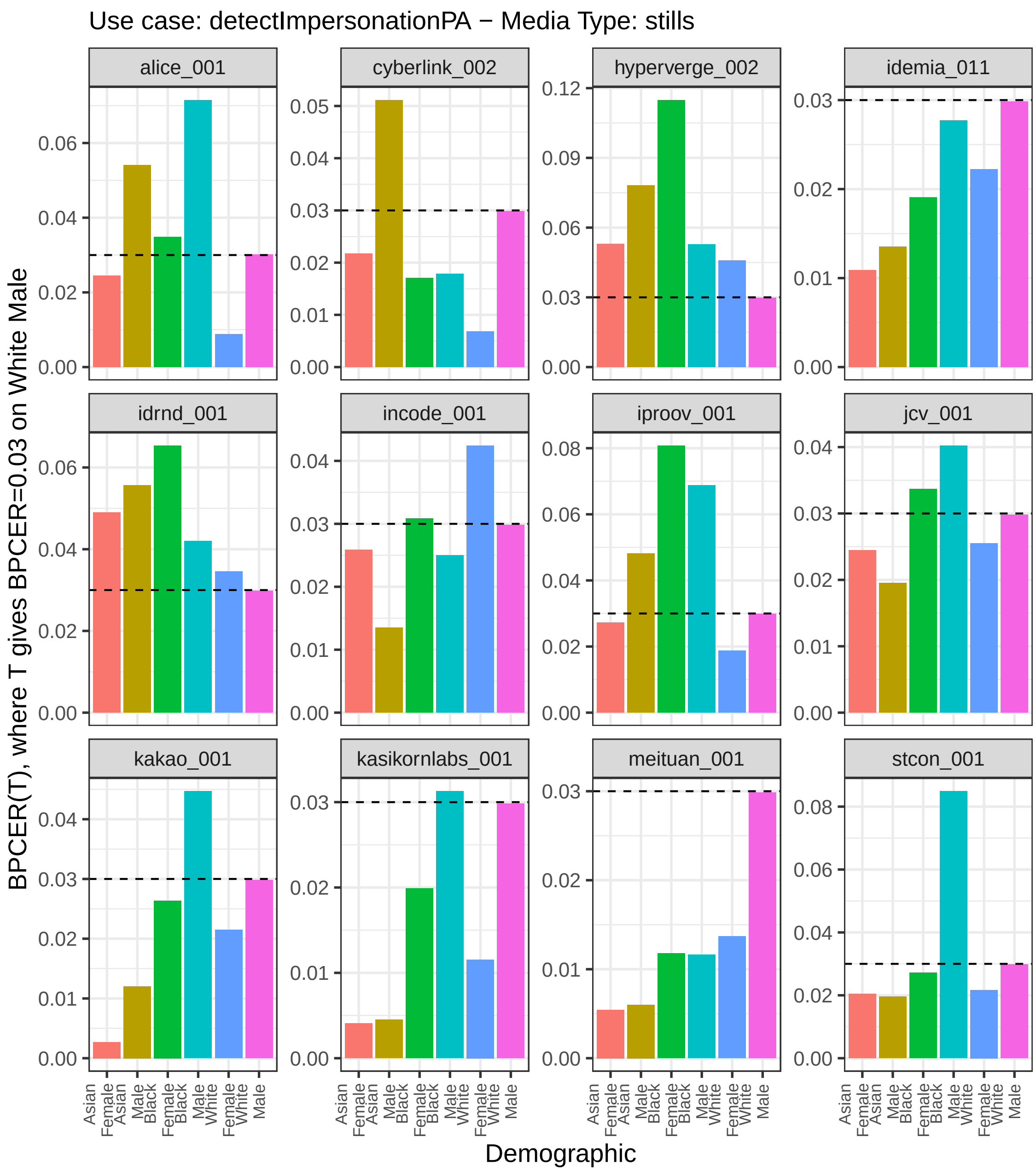



**Fig. 10.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male.

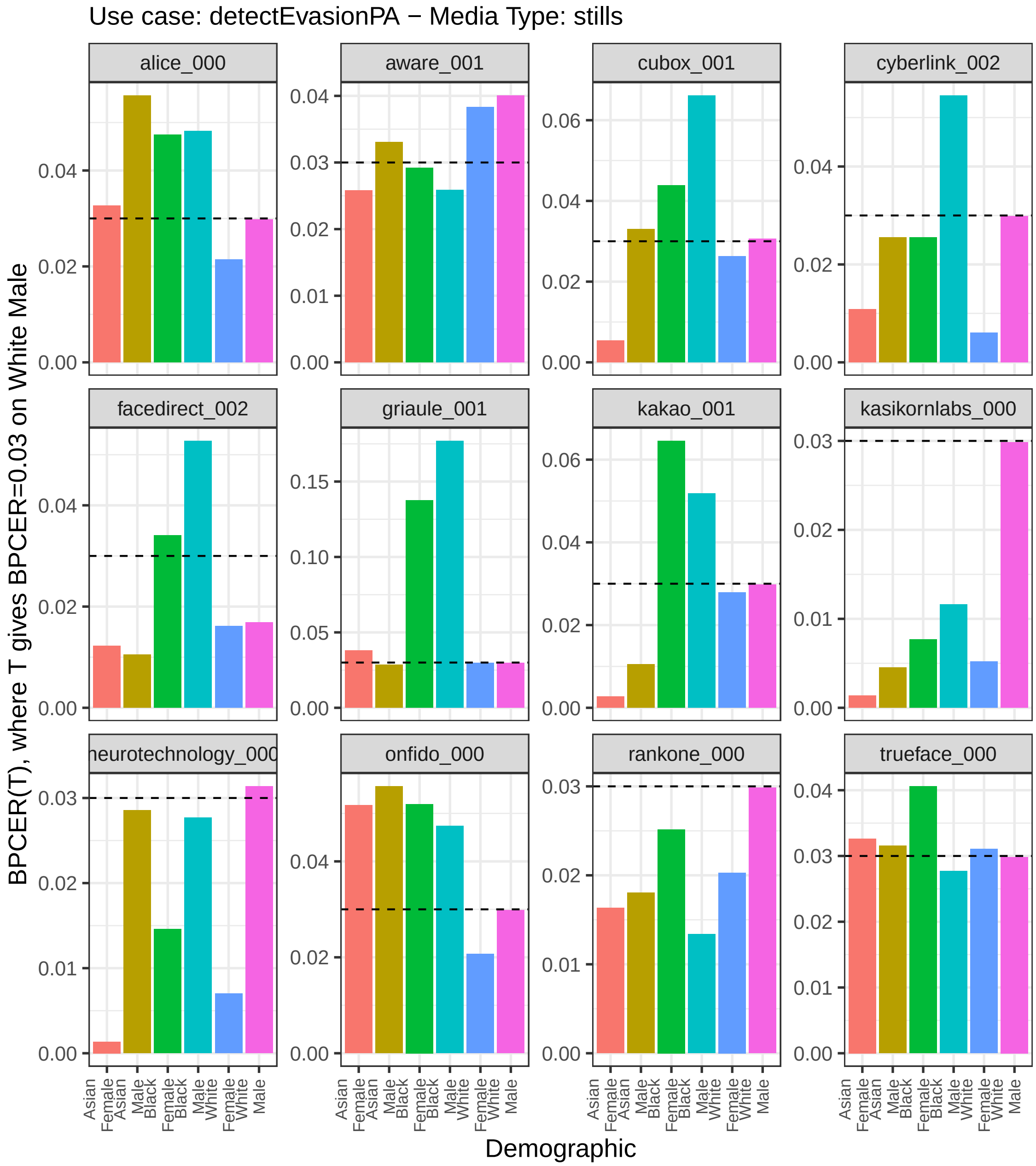



**Fig. 11.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male.

## References

[1] JTC1/SC37 (2023) International Organization for Standardization: Information Technology – Biometric presentation attack detection – Part 1: Framework. *ISO/IEC 30107-1*, Vol. 2, pp 1–11. https://www.iso.org/standard/83828.html.

[2] JTC1/SC37 (2023) International Organization for Standardization: Information Technology – Biometric presentation attack detection – Part 3: Testing and reporting. *ISO/IEC 30107-3*, Vol. 2, pp 1–39. https://www.iso.org/standard/79520.html.

[3] Matsumoto T, Matsumoto H, Yamada K, Hoshino S (2002) Impact of artificial "gummy" fingers on fingerprint systems. *Optical Security and Counterfeit Deterrence Techniques IV*, ed van Renesse RL, *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, Vol. 4677, pp 275–289. https://doi.org/10.1117/12.462719

[4] Sobell MG (2015) *A practical guide to Ubuntu Linux* (Pearson Education), 4th Ed. https://www.cl72.org/130gnuOS/sobell_ubuntu-linux.pdf.

[5] Berg EJ (1936) *Heaviside's operational calculus as applied to engineering and physics*. Electrical engineering texts (McGraw-Hill book company, inc.), 2nd Ed. Available at https://books.google.com/books?id=jZw8AAAAIAAJ.

[6] Ngan M, Grother P, Hanaoka K, Hom A, Yang J (2023) PAD Concept, Evaluation Plan, and API. https://pages.nist.gov/frvt/api/FRVT_pad_api.pdf.

## Appendix A. Detailed Algorithm Results

### Appendix A.1. Timing

**Table 29.** Timing Statistics. This table includes the median duration (in microseconds) for each of the PAD function calls implemented in the algorithm submission. Timing was conducted over 1000 invocations of each function with a single input image of 1280x960 pixels. We measure the duration of all function calls using the C++ std::chrono::high resolution clock on an unloaded server-class machine.

| Algorithm | detectImpersonationPA | detectEvasionPA |
|---|---|---|
| alchera_000 | 626762 | 426061 |
| alice_000 | 567992 | 569786 |
| alice_001 | 1914308 | NOT IMPLEMENTED |
| aware_001 | 574519 | 1108573 |
| aware_002 | 489973 | 646029 |
| biocube_001 | 406687 | NOT IMPLEMENTED |
| biocube_002 | 373057 | NOT IMPLEMENTED |
| cubox_000 | 240890 | 241108 |
| cubox_001 | 170798 | 171028 |
| cyberlink_001 | 1356072 | 533984 |
| cyberlink_002 | 3310836 | 3260528 |
| facedirect_001 | 2577671 | 2575817 |
| facedirect_002 | 3551555 | 3545257 |
| facephi_000 | 1623628 | NOT IMPLEMENTED |
| facephi_001 | 1608413 | NOT IMPLEMENTED |
| griaule_000 | 233144 | 178602 |
| griaule_001 | 207018 | 178152 |
| hyperverge_001 | 828545 | NOT IMPLEMENTED |
| hyperverge_002 | 1336211 | NOT IMPLEMENTED |
| id3_001 | 54276 | NOT IMPLEMENTED |
| idemia_010 | 1437127 | NOT IMPLEMENTED |
| idemia_011 | 1548429 | NOT IMPLEMENTED |
| idrnd_000 | 1071149 | NOT IMPLEMENTED |
| idrnd_001 | 2211383 | NOT IMPLEMENTED |
| idvisioncenter_001 | 1209794 | NOT IMPLEMENTED |
| idvisioncenter_002 | 1158366 | NOT IMPLEMENTED |
| iidentifii_000 | 454321 | NOT IMPLEMENTED |
| incode_000 | 409352 | NOT IMPLEMENTED |
| incode_001 | 168563 | NOT IMPLEMENTED |
| innovatrics_001 | 161316 | NOT IMPLEMENTED |
| innovatrics_002 | 82371 | NOT IMPLEMENTED |
| intema_000 | 240864 | NOT IMPLEMENTED |
| intema_001 | 438294 | NOT IMPLEMENTED |
| iproov_000 | 481197 | NOT IMPLEMENTED |
| iproov_001 | 478453 | NOT IMPLEMENTED |
| jcv_001 | 1960542 | 1 |
| jcv_002 | 1935989 | NOT IMPLEMENTED |

**Table 29.** Timing Statistics. This table includes the median duration (in microseconds) for each of the PAD function calls implemented in the algorithm submission. Timing was conducted over 1000 invocations of each function with a single input image of 1280x960 pixels. We measure the duration of all function calls using the C++ std::chrono::high resolution clock on an unloaded server-class machine. *(continued)*

| Algorithm | detectImpersonationPA | detectEvasionPA |
|---|---|---|
| kakao_000 | 305931 | 307309 |
| kakao_001 | 1994309 | 2000002 |
| kasikornlabs_000 | 203020 | 203208 |
| kasikornlabs_001 | 198511 | 196694 |
| mbsolutions_000 | 165928 | NOT IMPLEMENTED |
| mbsolutions_001 | 344484 | NOT IMPLEMENTED |
| meituan_000 | 1679511 | NOT IMPLEMENTED |
| meituan_001 | 1210108 | NOT IMPLEMENTED |
| mobbl_000 | 167501 | NOT IMPLEMENTED |
| mobbl_001 | 26255 | NOT IMPLEMENTED |
| neurotechnology_000 | 767681 | 768336 |
| neurotechnology_001 | 523325 | 522281 |
| nsensekorea_000 | 52092 | NOT IMPLEMENTED |
| nsensekorea_001 | 54822 | NOT IMPLEMENTED |
| onfido_000 | 317243 | 319279 |
| onfido_001 | 318573 | 318255 |
| papago_001 | 426208 | 425695 |
| pxl_000 | 66307 | NOT IMPLEMENTED |
| pxl_001 | 64185 | NOT IMPLEMENTED |
| rankone_000 | 417360 | 219247 |
| rankone_001 | 412683 | 217497 |
| saffe_001 | 17277 | NOT IMPLEMENTED |
| saffe_002 | 26799 | NOT IMPLEMENTED |
| spooff_000 | 158543 | 384100 |
| stcon_000 | 1877903 | NOT IMPLEMENTED |
| stcon_001 | 3692479 | NOT IMPLEMENTED |
| tech5_001 | 142069 | NOT IMPLEMENTED |
| techsign_000 | 565129 | NOT IMPLEMENTED |
| techsign_001 | 869578 | NOT IMPLEMENTED |
| trueface_000 | 250897 | 1732879 |
| uxlabs_001 | 201687 | 201675 |
| veridas_001 | 613979 | NOT IMPLEMENTED |
| veridas_002 | 1912806 | NOT IMPLEMENTED |
| verigram_000 | 380375 | NOT IMPLEMENTED |
| verigram_001 | 828047 | NOT IMPLEMENTED |
| verihubs-inteligensia_000 | 74964 | NOT IMPLEMENTED |
| verihubs-inteligensia_001 | 89524 | NOT IMPLEMENTED |
| vida_001 | 87030 | NOT IMPLEMENTED |
| vida_002 | 106467 | NOT IMPLEMENTED |
| visteam_001 | 85377 | NOT IMPLEMENTED |
| visteam_002 | 68138 | NOT IMPLEMENTED |
| yoonik_001 | 765220 | NOT IMPLEMENTED |

**Table 29.** Timing Statistics. This table includes the median duration (in microseconds) for each of the PAD function calls implemented in the algorithm submission. Timing was conducted over 1000 invocations of each function with a single input image of 1280x960 pixels. We measure the duration of all function calls using the C++ std::chrono::high resolution clock on an unloaded server-class machine. *(continued)*

| Algorithm | detectImpersonationPA | detectEvasionPA |
|---|---|---|
| yoonik_002 | 926897 | NOT IMPLEMENTED |
| yoti_001 | 10590583 | NOT IMPLEMENTED |
| yoti_002 | 10605311 | NOT IMPLEMENTED |

## Appendix A.2. Impersonation

**Table 30.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.000 | 0.000 | 0.07 ± 0.01 | 1 | 0.105 | 3 |
| idrnd-001 | 0.000 | 0.000 | 0.1 ± 0.02 | 2 | 0.082 | 2 |
| idrnd-000 | 0.000 | 0.000 | 0.12 ± 0.02 | 3 | 0.133 | 4 |
| stcon-001 | 0.000 | 0.000 | 0.13 ± 0.02 | 4 | 0.346 | 7 |
| iproov-001 | 0.000 | 0.000 | 0.16 ± 0.02 | 5 | 0.377 | 10 |
| cyberlink-002 | 0.000 | 0.000 | 0.18 ± 0.02 | 6 | 0.207 | 5 |
| kakao-000 | 0.000 | 0.000 | 0.31 ± 0.03 | 7 | 0.719 | 27 |
| stcon-000 | 0.000 | 0.000 | 0.31 ± 0.03 | 8 | 0.482 | 13 |
| cyberlink-001 | 0.000 | 0.000 | 0.42 ± 0.03 | 9 | 0.382 | 11 |
| onfido-000 | 0.001 | 0.000 | 0.47 ± 0.03 | 10 | 0.825 | 37 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.52 ± 0.03 | 11 | 0.348 | 8 |
| alice-001 | 0.000 | 0.000 | 0.52 ± 0.03 | 12 | 1.000 | 67 |
| veridas-002 | 0.000 | 0.000 | 0.53 ± 0.03 | 13 | 0.524 | 14 |
| iidentifii-000 | 0.000 | 0.000 | 0.57 ± 0.03 | 14 | 0.753 | 31 |
| idemia-011 | 0.000 | 0.000 | 0.6 ± 0.03 | 15 | 0.779 | 34 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.6 ± 0.03 | 16 | 0.437 | 12 |
| hyperverge-002 | 0.000 | 0.000 | 0.63 ± 0.03 | 17 | 0.989 | 55 |
| aware-002 | 0.000 | 0.000 | 0.64 ± 0.03 | 18 | 0.356 | 9 |
| veridas-001 | 0.000 | 0.000 | 0.64 ± 0.03 | 19 | 0.555 | 16 |
| incode-001 | 0.000 | 0.000 | 0.64 ± 0.03 | 20 | 1.000 | 67 |
| onfido-001 | 0.001 | 0.000 | 0.65 ± 0.03 | 21 | 0.720 | 28 |
| hyperverge-001 | 0.000 | 0.000 | 0.67 ± 0.03 | 22 | 1.000 | 67 |
| intema-001 | 0.000 | 0.000 | 0.72 ± 0.03 | 23 | 0.574 | 19 |
| meituan-001 | 0.000 | 0.000 | 0.73 ± 0.03 | 24 | 1.000 | 67 |
| neurotechnology-000 | 0.000 | 0.000 | 0.74 ± 0.03 | 25 | 1.000 | 67 |
| innovatrics-002 | 0.000 | 0.000 | 0.76 ± 0.03 | 26 | 0.744 | 30 |
| intema-000 | 0.000 | 0.000 | 0.79 ± 0.02 | 27 | 0.635 | 23 |
| rankone-000 | 0.000 | 0.000 | 0.79 ± 0.02 | 28 | 0.728 | 29 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.8 ± 0.02 | 29 | 0.712 | 26 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.81 ± 0.02 | 30 | 0.893 | 40 |
| visteam-002 | 0.000 | 0.000 | 0.84 ± 0.02 | 31 | 1.000 | 67 |
| facedirect-002 | 0.000 | 0.000 | 0.84 ± 0.02 | 32 | 1.000 | 67 |
| innovatrics-001 | 0.000 | 0.000 | 0.85 ± 0.02 | 33 | 0.688 | 25 |
| vida-002 | 0.000 | 0.000 | 0.85 ± 0.02 | 34 | 0.978 | 52 |
| mbsolutions-001 | 0.069 | 0.007 | 0.85 ± 0.02 | 35 | 1.000 | 67 |
| saffe-002 | 0.001 | 0.000 | 0.86 ± 0.02 | 36 | 0.913 | 41 |
| idemia-010 | 0.002 | 0.000 | 0.86 ± 0.02 | 37 | 0.580 | 20 |
| facedirect-001 | 0.000 | 0.000 | 0.88 ± 0.02 | 38 | 0.967 | 50 |
| incode-000 | 0.000 | 0.000 | 0.89 ± 0.02 | 39 | 0.536 | 15 |

**Table 30.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| saffe-001 | 0.001 | 0.000 | 0.9 ± 0.02 | 40 | 0.956 | 47 |
| meituan-000 | 0.000 | 0.000 | 0.9 ± 0.02 | 41 | 0.989 | 55 |
| vida-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 42 | 0.966 | 49 |
| jcv-001 | 0.002 | 0.000 | 0.92 ± 0.02 | 43 | 1.000 | 67 |
| rankone-001 | 0.000 | 0.000 | 0.92 ± 0.02 | 44 | 0.762 | 32 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.92 ± 0.02 | 45 | 0.988 | 54 |
| jcv-002 | 0.002 | 0.000 | 0.93 ± 0.02 | 46 | 1.000 | 67 |
| griaule-001 | 0.000 | 0.000 | 0.94 ± 0.01 | 47 | 1.000 | 67 |
| mbsolutions-000 | 0.000 | 0.000 | 0.94 ± 0.01 | 48 | 1.000 | 67 |
| pxl-001 | 0.001 | 0.000 | 0.94 ± 0.01 | 49 | 0.929 | 42 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.95 ± 0.01 | 50 | 0.967 | 50 |
| visteam-001 | 0.000 | 0.000 | 0.96 ± 0.01 | 51 | 0.998 | 58 |
| verigram-001 | 0.000 | 0.000 | 0.96 ± 0.01 | 52 | 0.863 | 38 |
| techsign-001 | 0.007 | 0.007 | 0.96 ± 0.01 | 53 | 1.000 | 67 |
| biocube-001 | 0.000 | 0.000 | 0.96 ± 0.01 | 54 | 0.961 | 48 |
| techsign-000 | 0.000 | 0.000 | 0.96 ± 0.01 | 55 | 1.000 | 59 |
| yoonik-002 | 0.000 | 0.000 | 0.96 ± 0.01 | 56 | 0.945 | 45 |
| nsensekorea-001 | 0.000 | 0.000 | 0.97 ± 0.01 | 57 | 1.000 | 59 |
| biocube-002 | 0.000 | 0.000 | 0.97 ± 0.01 | 58 | 1.000 | 67 |
| nsensekorea-000 | 0.000 | 0.000 | 0.97 ± 0.01 | 58 | 1.000 | 59 |
| id3-001 | 0.000 | 0.000 | 0.973 ± 0.009 | 60 | 0.871 | 39 |
| cubox-000 | 0.000 | 0.000 | 0.979 ± 0.008 | 61 | 1.000 | 59 |
| mobbl-000 | 0.000 | 0.000 | 0.984 ± 0.008 | 62 | 0.978 | 52 |
| verigram-000 | 0.000 | 0.000 | 0.985 ± 0.007 | 63 | 0.934 | 43 |
| spooff-000 | 0.000 | 0.000 | 0.986 ± 0.007 | 64 | 0.952 | 46 |
| cubox-001 | 0.000 | 0.000 | 0.987 ± 0.007 | 65 | 1.000 | 59 |
| papago-001 | 0.000 | 0.000 | 0.987 ± 0.007 | 66 | 1.000 | 59 |
| mobbl-001 | 0.000 | 0.000 | 0.996 ± 0.004 | 67 | 0.989 | 55 |
| tech5-001 | 0.001 | 0.002 | 0.996 ± 0.004 | 67 | 1.000 | 67 |
| alchera-000 | 0.000 | 0.000 | 0.999 ± 0.001 | 69 | 1.000 | 59 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.565 | 18 |
| aware-001 | 0.151 | 0.035 | 1 ± 0 | 70 | 0.308 | 6 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.773 | 33 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.687 | 24 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 1.000 | 67 |
| iproov-000 | 0.102 | 0.016 | 1 ± 0 | 70 | 0.069 | 1 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.813 | 36 |
| pxl-000 | 0.001 | 0.000 | 1 ± 0 | 70 | 1.000 | 59 |
| trueface-000 | 0.296 | 0.271 | 1 ± 0 | 70 | 0.810 | 35 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.560 | 17 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.934 | 43 |

**Table 30.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| yoti-001 | 0.467 | 0.388 | 1 ± 0 | 70 | 0.628 | 21 |
| yoti-002 | 0.463 | 0.393 | 1 ± 0 | 70 | 0.628 | 21 |

**Table 31.** PA Type 3 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| stcon-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 1 |
| stcon-000 | 0.000 | 0.000 | 0.005 ± 0.007 | 2 | 0.006 | 3 |
| alice-001 | 0.000 | 0.000 | 0.01 ± 0.01 | 3 | 0.004 | 2 |
| cyberlink-002 | 0.000 | 0.000 | 0.01 ± 0.01 | 3 | 0.007 | 4 |
| idrnd-001 | 0.000 | 0.000 | 0.02 ± 0.02 | 5 | 0.012 | 5 |
| incode-001 | 0.000 | 0.000 | 0.02 ± 0.02 | 5 | 0.070 | 15 |
| idrnd-000 | 0.000 | 0.000 | 0.03 ± 0.02 | 7 | 0.027 | 9 |
| cyberlink-001 | 0.000 | 0.000 | 0.03 ± 0.02 | 8 | 0.020 | 7 |
| onfido-000 | 0.000 | 0.000 | 0.05 ± 0.03 | 9 | 0.036 | 10 |
| iidentifii-000 | 0.000 | 0.000 | 0.06 ± 0.03 | 10 | 0.062 | 14 |
| iproov-001 | 0.000 | 0.000 | 0.07 ± 0.04 | 11 | 0.248 | 25 |
| onfido-001 | 0.000 | 0.000 | 0.09 ± 0.04 | 12 | 0.051 | 12 |
| aware-002 | 0.000 | 0.000 | 0.1 ± 0.04 | 13 | 0.056 | 13 |
| innovatrics-002 | 0.000 | 0.000 | 0.11 ± 0.05 | 14 | 0.098 | 17 |
| facedirect-002 | 0.000 | 0.000 | 0.16 ± 0.05 | 15 | 0.989 | 66 |
| veridas-002 | 0.000 | 0.000 | 0.25 ± 0.06 | 16 | 0.260 | 27 |
| neurotechnology-000 | 0.000 | 0.000 | 0.26 ± 0.06 | 17 | 0.197 | 23 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.26 ± 0.06 | 18 | 0.251 | 26 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.29 ± 0.06 | 19 | 0.329 | 30 |
| innovatrics-001 | 0.000 | 0.000 | 0.32 ± 0.06 | 20 | 0.352 | 31 |
| idemia-011 | 0.000 | 0.000 | 0.35 ± 0.06 | 21 | 0.161 | 20 |
| intema-001 | 0.000 | 0.000 | 0.39 ± 0.07 | 22 | 0.181 | 21 |
| intema-000 | 0.000 | 0.000 | 0.42 ± 0.07 | 23 | 0.352 | 32 |
| kakao-001 | 0.000 | 0.000 | 0.49 ± 0.07 | 24 | 0.365 | 33 |
| incode-000 | 0.000 | 0.000 | 0.52 ± 0.07 | 25 | 0.085 | 16 |
| meituan-001 | 0.000 | 0.000 | 0.54 ± 0.07 | 26 | 1.000 | 74 |
| rankone-000 | 0.000 | 0.000 | 0.56 ± 0.07 | 27 | 0.423 | 34 |
| meituan-000 | 0.000 | 0.000 | 0.6 ± 0.07 | 28 | 0.934 | 51 |
| veridas-001 | 0.000 | 0.000 | 0.61 ± 0.07 | 29 | 0.284 | 28 |
| jcv-001 | 0.000 | 0.000 | 0.62 ± 0.07 | 30 | 1.000 | 74 |
| jcv-002 | 0.000 | 0.000 | 0.62 ± 0.07 | 30 | 1.000 | 74 |
| idemia-010 | 0.000 | 0.000 | 0.65 ± 0.07 | 32 | 0.240 | 24 |
| kakao-000 | 0.000 | 0.000 | 0.67 ± 0.06 | 33 | 0.824 | 45 |
| vida-002 | 0.000 | 0.000 | 0.7 ± 0.06 | 34 | 0.643 | 41 |
| visteam-002 | 0.000 | 0.000 | 0.71 ± 0.06 | 35 | 0.184 | 22 |
| hyperverge-001 | 0.000 | 0.000 | 0.72 ± 0.06 | 36 | 1.000 | 74 |
| hyperverge-002 | 0.000 | 0.000 | 0.72 ± 0.06 | 36 | 1.000 | 69 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.77 ± 0.06 | 38 | 0.976 | 62 |
| facedirect-001 | 0.000 | 0.000 | 0.77 ± 0.06 | 39 | 0.536 | 37 |
| mbsolutions-001 | 0.039 | 0.007 | 0.79 ± 0.06 | 40 | 1.000 | 74 |
| saffe-002 | 0.000 | 0.000 | 0.82 ± 0.05 | 41 | 0.873 | 48 |

**Table 31.** PA Type 3 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| vida-001 | 0.000 | 0.000 | 0.83 ± 0.05 | 42 | 0.825 | 46 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.86 ± 0.05 | 43 | 0.967 | 57 |
| saffe-001 | 0.000 | 0.000 | 0.88 ± 0.04 | 44 | 0.883 | 49 |
| rankone-001 | 0.000 | 0.000 | 0.88 ± 0.04 | 45 | 0.512 | 36 |
| techsign-001 | 0.010 | 0.007 | 0.9 ± 0.04 | 46 | 0.699 | 43 |
| verigram-001 | 0.000 | 0.000 | 0.91 ± 0.04 | 47 | 0.934 | 52 |
| griaule-001 | 0.000 | 0.000 | 0.91 ± 0.04 | 48 | 1.000 | 74 |
| cubox-000 | 0.000 | 0.000 | 0.92 ± 0.04 | 49 | 0.967 | 57 |
| mobbl-001 | 0.000 | 0.000 | 0.94 ± 0.03 | 50 | 0.967 | 57 |
| cubox-001 | 0.000 | 0.000 | 0.95 ± 0.03 | 51 | 0.934 | 53 |
| visteam-001 | 0.000 | 0.000 | 0.95 ± 0.03 | 51 | 0.967 | 57 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.95 ± 0.03 | 53 | 0.853 | 47 |
| biocube-001 | 0.000 | 0.000 | 0.96 ± 0.03 | 54 | 0.995 | 68 |
| biocube-002 | 0.000 | 0.000 | 0.96 ± 0.03 | 54 | 1.000 | 74 |
| verigram-000 | 0.000 | 0.000 | 0.96 ± 0.03 | 56 | 0.945 | 56 |
| yoonik-002 | 0.000 | 0.000 | 0.96 ± 0.03 | 56 | 0.945 | 55 |
| pxl-001 | 0.000 | 0.000 | 0.97 ± 0.02 | 58 | 0.555 | 39 |
| mbsolutions-000 | 0.000 | 0.000 | 0.97 ± 0.02 | 59 | 1.000 | 74 |
| spooff-000 | 0.000 | 0.000 | 0.97 ± 0.02 | 59 | 0.975 | 61 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.98 ± 0.02 | 61 | 0.762 | 44 |
| nsensekorea-000 | 0.000 | 0.000 | 0.98 ± 0.02 | 61 | 1.000 | 69 |
| nsensekorea-001 | 0.000 | 0.000 | 0.98 ± 0.02 | 61 | 1.000 | 69 |
| id3-001 | 0.000 | 0.000 | 0.995 ± 0.007 | 64 | 0.944 | 54 |
| papago-001 | 0.000 | 0.000 | 0.995 ± 0.007 | 64 | 0.989 | 63 |
| tech5-001 | 0.005 | 0.002 | 0.995 ± 0.007 | 64 | 0.994 | 67 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 1.000 | 69 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.014 | 6 |
| aware-001 | 0.072 | 0.035 | 1 ± 0 | 67 | 0.045 | 11 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.152 | 19 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.124 | 18 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 1.000 | 74 |
| iproov-000 | 0.068 | 0.016 | 1 ± 0 | 67 | 0.021 | 8 |
| mobbl-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.989 | 63 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.294 | 29 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 1.000 | 69 |
| techsign-000 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.989 | 63 |
| trueface-000 | 0.261 | 0.271 | 1 ± 0 | 67 | 0.686 | 42 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.447 | 35 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 67 | 0.913 | 50 |
| yoti-001 | 0.473 | 0.388 | 1 ± 0 | 67 | 0.548 | 38 |
| yoti-002 | 0.473 | 0.393 | 1 ± 0 | 67 | 0.580 | 40 |

**Table 32.** PA Type 4 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| cyberlink-002 | 0.000 | 0.000 | 0.13 ± 0.03 | 1 | 0.207 | 2 |
| cyberlink-001 | 0.000 | 0.000 | 0.18 ± 0.03 | 2 | 0.408 | 7 |
| stcon-001 | 0.000 | 0.000 | 0.19 ± 0.03 | 3 | 0.670 | 20 |
| stcon-000 | 0.000 | 0.000 | 0.29 ± 0.04 | 4 | 0.771 | 26 |
| idrnd-001 | 0.000 | 0.000 | 0.42 ± 0.04 | 5 | 0.395 | 5 |
| idrnd-000 | 0.000 | 0.000 | 0.47 ± 0.04 | 6 | 0.395 | 5 |
| meituan-001 | 0.000 | 0.000 | 0.53 ± 0.04 | 7 | 1.000 | 68 |
| iproov-001 | 0.000 | 0.000 | 0.55 ± 0.04 | 8 | 0.613 | 13 |
| alice-001 | 0.000 | 0.000 | 0.56 ± 0.04 | 9 | 1.000 | 68 |
| jcv-001 | 0.000 | 0.000 | 0.59 ± 0.04 | 10 | 0.881 | 36 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.62 ± 0.04 | 11 | 0.452 | 9 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.62 ± 0.04 | 12 | 0.555 | 11 |
| jcv-002 | 0.000 | 0.000 | 0.63 ± 0.04 | 13 | 1.000 | 68 |
| vida-001 | 0.000 | 0.000 | 0.64 ± 0.04 | 14 | 0.447 | 8 |
| meituan-000 | 0.000 | 0.000 | 0.66 ± 0.04 | 15 | 0.956 | 48 |
| kakao-001 | 0.000 | 0.000 | 0.66 ± 0.04 | 16 | 0.649 | 17 |
| intema-000 | 0.000 | 0.000 | 0.7 ± 0.04 | 17 | 0.628 | 16 |
| intema-001 | 0.000 | 0.000 | 0.7 ± 0.04 | 18 | 0.463 | 10 |
| idemia-011 | 0.000 | 0.000 | 0.71 ± 0.04 | 19 | 0.621 | 14 |
| onfido-001 | 0.000 | 0.000 | 0.74 ± 0.03 | 20 | 0.621 | 15 |
| veridas-002 | 0.000 | 0.000 | 0.75 ± 0.03 | 21 | 0.797 | 28 |
| aware-002 | 0.000 | 0.000 | 0.76 ± 0.03 | 22 | 0.322 | 4 |
| iidentifii-000 | 0.000 | 0.000 | 0.77 ± 0.03 | 23 | 0.704 | 23 |
| vida-002 | 0.000 | 0.000 | 0.81 ± 0.03 | 24 | 0.934 | 42 |
| onfido-000 | 0.000 | 0.000 | 0.82 ± 0.03 | 25 | 0.788 | 27 |
| hyperverge-002 | 0.000 | 0.000 | 0.82 ± 0.03 | 26 | 1.000 | 62 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.84 ± 0.03 | 27 | 0.893 | 37 |
| incode-001 | 0.000 | 0.000 | 0.84 ± 0.03 | 28 | 1.000 | 68 |
| hyperverge-001 | 0.000 | 0.000 | 0.84 ± 0.03 | 29 | 1.000 | 68 |
| veridas-001 | 0.000 | 0.000 | 0.86 ± 0.03 | 30 | 0.762 | 25 |
| innovatrics-002 | 0.000 | 0.000 | 0.88 ± 0.03 | 31 | 0.873 | 35 |
| kakao-000 | 0.000 | 0.000 | 0.88 ± 0.03 | 32 | 0.931 | 40 |
| incode-000 | 0.000 | 0.000 | 0.89 ± 0.03 | 33 | 0.806 | 29 |
| facedirect-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 34 | 0.989 | 57 |
| idemia-010 | 0.000 | 0.000 | 0.9 ± 0.02 | 35 | 0.665 | 18 |
| cubox-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 36 | 0.967 | 52 |
| innovatrics-001 | 0.000 | 0.000 | 0.91 ± 0.02 | 37 | 0.711 | 24 |
| neurotechnology-000 | 0.000 | 0.000 | 0.91 ± 0.02 | 38 | 1.000 | 68 |
| techsign-001 | 0.003 | 0.007 | 0.91 ± 0.02 | 39 | 1.000 | 68 |
| visteam-002 | 0.000 | 0.000 | 0.92 ± 0.02 | 40 | 1.000 | 68 |
| mbsolutions-001 | 0.050 | 0.007 | 0.92 ± 0.02 | 41 | 1.000 | 68 |

**Table 32.** PA Type 4 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| rankone-001 | 0.000 | 0.000 | 0.92 ± 0.02 | 42 | 0.834 | 31 |
| saffe-002 | 0.000 | 0.000 | 0.92 ± 0.02 | 43 | 0.934 | 43 |
| griaule-001 | 0.000 | 0.000 | 0.93 ± 0.02 | 44 | 1.000 | 68 |
| mbsolutions-000 | 0.000 | 0.000 | 0.95 ± 0.02 | 45 | 1.000 | 68 |
| cubox-000 | 0.000 | 0.000 | 0.95 ± 0.02 | 46 | 0.967 | 52 |
| rankone-000 | 0.000 | 0.000 | 0.95 ± 0.02 | 46 | 0.924 | 38 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.95 ± 0.02 | 46 | 0.989 | 57 |
| verigram-001 | 0.000 | 0.000 | 0.96 ± 0.02 | 49 | 0.966 | 51 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.96 ± 0.01 | 50 | 0.934 | 41 |
| saffe-001 | 0.000 | 0.000 | 0.96 ± 0.01 | 50 | 0.934 | 43 |
| visteam-001 | 0.000 | 0.000 | 0.96 ± 0.02 | 50 | 0.967 | 52 |
| tech5-001 | 0.000 | 0.002 | 0.98 ± 0.01 | 53 | 1.000 | 68 |
| techsign-000 | 0.000 | 0.000 | 0.98 ± 0.01 | 53 | 0.945 | 47 |
| facedirect-002 | 0.000 | 0.000 | 0.98 ± 0.01 | 55 | 0.989 | 61 |
| pxl-001 | 0.000 | 0.000 | 0.98 ± 0.01 | 55 | 0.835 | 32 |
| spooff-000 | 0.000 | 0.000 | 0.987 ± 0.009 | 57 | 0.960 | 49 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.99 ± 0.007 | 58 | 0.924 | 38 |
| yoonik-002 | 0.000 | 0.000 | 0.99 ± 0.007 | 58 | 0.945 | 45 |
| alchera-000 | 0.000 | 0.000 | 0.992 ± 0.007 | 60 | 1.000 | 62 |
| id3-001 | 0.000 | 0.000 | 0.992 ± 0.007 | 60 | 0.861 | 34 |
| mobbl-001 | 0.000 | 0.000 | 0.992 ± 0.007 | 60 | 0.989 | 57 |
| papago-001 | 0.000 | 0.000 | 0.992 ± 0.007 | 60 | 0.989 | 57 |
| biocube-001 | 0.000 | 0.000 | 0.994 ± 0.006 | 64 | 0.984 | 56 |
| biocube-002 | 0.000 | 0.000 | 0.995 ± 0.006 | 65 | 1.000 | 68 |
| nsensekorea-000 | 0.000 | 0.000 | 0.995 ± 0.006 | 65 | 1.000 | 62 |
| nsensekorea-001 | 0.000 | 0.000 | 0.995 ± 0.006 | 65 | 1.000 | 62 |
| mobbl-000 | 0.000 | 0.000 | 0.998 ± 0.002 | 68 | 0.978 | 55 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.813 | 30 |
| aware-001 | 0.139 | 0.035 | 1 ± 0 | 69 | 0.200 | 1 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.610 | 12 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.677 | 22 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 69 | 1.000 | 68 |
| iproov-000 | 0.073 | 0.016 | 1 ± 0 | 69 | 0.315 | 3 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.853 | 33 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 69 | 1.000 | 62 |
| trueface-000 | 0.181 | 0.271 | 1 ± 0 | 69 | 1.000 | 68 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.964 | 50 |
| verigram-000 | 0.000 | 0.000 | 1 ± 0 | 69 | 1.000 | 62 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 69 | 0.945 | 45 |
| yoti-001 | 0.380 | 0.388 | 1 ± 0 | 69 | 0.672 | 21 |
| yoti-002 | 0.438 | 0.393 | 1 ± 0 | 69 | 0.665 | 18 |

**Table 33.** PA Type 7 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| cyberlink-002 | 0.000 | 0.000 | 0.012 ± 0.003 | 1 | 0.012 | 1 |
| cyberlink-001 | 0.000 | 0.000 | 0.052 ± 0.006 | 2 | 0.095 | 2 |
| kakao-001 | 0.000 | 0.000 | 0.06 ± 0.007 | 3 | 0.159 | 3 |
| alice-001 | 0.000 | 0.000 | 0.108 ± 0.009 | 4 | 0.345 | 8 |
| kakao-000 | 0.000 | 0.000 | 0.16 ± 0.01 | 5 | 0.703 | 31 |
| hyperverge-002 | 0.000 | 0.000 | 0.31 ± 0.01 | 6 | 0.989 | 60 |
| veridas-002 | 0.000 | 0.000 | 0.32 ± 0.01 | 7 | 0.291 | 6 |
| onfido-001 | 0.000 | 0.000 | 0.33 ± 0.01 | 8 | 0.263 | 4 |
| idrnd-000 | 0.000 | 0.000 | 0.33 ± 0.01 | 9 | 0.348 | 9 |
| idrnd-001 | 0.000 | 0.000 | 0.42 ± 0.01 | 10 | 0.356 | 10 |
| onfido-000 | 0.000 | 0.000 | 0.42 ± 0.01 | 11 | 0.696 | 30 |
| hyperverge-001 | 0.000 | 0.000 | 0.47 ± 0.01 | 12 | 1.000 | 68 |
| idemia-011 | 0.000 | 0.000 | 0.48 ± 0.01 | 13 | 0.643 | 28 |
| vida-002 | 0.000 | 0.000 | 0.5 ± 0.01 | 14 | 0.594 | 25 |
| veridas-001 | 0.000 | 0.000 | 0.5 ± 0.01 | 15 | 0.297 | 7 |
| iproov-001 | 0.000 | 0.000 | 0.51 ± 0.01 | 16 | 0.489 | 17 |
| rankone-000 | 0.000 | 0.000 | 0.56 ± 0.01 | 17 | 0.530 | 23 |
| vida-001 | 0.000 | 0.000 | 0.62 ± 0.01 | 18 | 0.524 | 21 |
| incode-001 | 0.000 | 0.000 | 0.62 ± 0.01 | 19 | 1.000 | 68 |
| meituan-001 | 0.000 | 0.000 | 0.64 ± 0.01 | 20 | 1.000 | 68 |
| stcon-000 | 0.000 | 0.000 | 0.64 ± 0.01 | 21 | 0.729 | 35 |
| jcv-001 | 0.001 | 0.000 | 0.65 ± 0.01 | 22 | 1.000 | 68 |
| neurotechnology-000 | 0.000 | 0.000 | 0.65 ± 0.01 | 23 | 0.525 | 22 |
| meituan-000 | 0.000 | 0.000 | 0.69 ± 0.01 | 24 | 0.978 | 54 |
| jcv-002 | 0.001 | 0.000 | 0.69 ± 0.01 | 25 | 1.000 | 68 |
| innovatrics-002 | 0.000 | 0.000 | 0.71 ± 0.01 | 26 | 0.275 | 5 |
| stcon-001 | 0.000 | 0.000 | 0.72 ± 0.01 | 27 | 0.747 | 36 |
| incode-000 | 0.000 | 0.000 | 0.72 ± 0.01 | 28 | 0.696 | 29 |
| verigram-001 | 0.000 | 0.000 | 0.74 ± 0.01 | 29 | 0.797 | 41 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.77 ± 0.01 | 30 | 0.815 | 43 |
| aware-002 | 0.000 | 0.000 | 0.8 ± 0.01 | 31 | 0.479 | 16 |
| intema-000 | 0.000 | 0.000 | 0.81 ± 0.01 | 32 | 0.770 | 38 |
| iidentifii-000 | 0.000 | 0.000 | 0.81 ± 0.01 | 33 | 0.873 | 45 |
| intema-001 | 0.000 | 0.000 | 0.82 ± 0.01 | 34 | 0.561 | 24 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.84 ± 0.01 | 35 | 0.728 | 33 |
| facedirect-001 | 0.000 | 0.000 | 0.84 ± 0.01 | 36 | 0.967 | 52 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.86 ± 0.01 | 37 | 0.753 | 37 |
| facedirect-002 | 0.000 | 0.000 | 0.86 ± 0.01 | 38 | 1.000 | 68 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.87 ± 0.01 | 39 | 0.844 | 44 |
| techsign-001 | 0.006 | 0.007 | 0.884 ± 0.009 | 40 | 1.000 | 68 |
| innovatrics-001 | 0.000 | 0.000 | 0.885 ± 0.009 | 41 | 0.711 | 32 |

**Table 33.** PA Type 7 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| griaule-001 | 0.000 | 0.000 | 0.887 ± 0.009 | 42 | 1.000 | 68 |
| idemia-010 | 0.000 | 0.000 | 0.892 ± 0.009 | 43 | 0.454 | 15 |
| mbsolutions-000 | 0.000 | 0.000 | 0.897 ± 0.009 | 44 | 1.000 | 68 |
| saffe-002 | 0.000 | 0.000 | 0.901 ± 0.009 | 45 | 0.924 | 47 |
| rankone-001 | 0.000 | 0.000 | 0.913 ± 0.008 | 46 | 0.728 | 33 |
| mbsolutions-001 | 0.047 | 0.007 | 0.918 ± 0.008 | 47 | 1.000 | 68 |
| saffe-001 | 0.000 | 0.000 | 0.922 ± 0.008 | 48 | 0.934 | 49 |
| cubox-001 | 0.000 | 0.000 | 0.949 ± 0.006 | 49 | 0.945 | 50 |
| yoonik-002 | 0.000 | 0.000 | 0.971 ± 0.005 | 50 | 0.806 | 42 |
| nsensekorea-001 | 0.000 | 0.000 | 0.971 ± 0.005 | 51 | 1.000 | 63 |
| nsensekorea-000 | 0.000 | 0.000 | 0.972 ± 0.005 | 52 | 1.000 | 63 |
| techsign-000 | 0.000 | 0.000 | 0.972 ± 0.005 | 53 | 0.978 | 55 |
| visteam-002 | 0.000 | 0.000 | 0.977 ± 0.004 | 54 | 1.000 | 68 |
| visteam-001 | 0.000 | 0.000 | 0.98 ± 0.004 | 55 | 0.977 | 53 |
| cubox-000 | 0.000 | 0.000 | 0.98 ± 0.004 | 56 | 0.989 | 60 |
| verigram-000 | 0.000 | 0.000 | 0.984 ± 0.004 | 57 | 1.000 | 63 |
| papago-001 | 0.000 | 0.000 | 0.987 ± 0.003 | 58 | 1.000 | 63 |
| mobbl-001 | 0.000 | 0.000 | 0.988 ± 0.003 | 59 | 0.978 | 55 |
| id3-001 | 0.000 | 0.000 | 0.99 ± 0.003 | 60 | 0.512 | 20 |
| spooff-000 | 0.000 | 0.000 | 0.99 ± 0.003 | 61 | 0.988 | 59 |
| pxl-001 | 0.000 | 0.000 | 0.992 ± 0.003 | 62 | 0.929 | 48 |
| biocube-002 | 0.000 | 0.000 | 0.992 ± 0.003 | 63 | 1.000 | 68 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.994 ± 0.002 | 64 | 0.965 | 51 |
| biocube-001 | 0.000 | 0.000 | 0.994 ± 0.002 | 65 | 0.984 | 58 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.995 ± 0.002 | 66 | 0.913 | 46 |
| tech5-001 | 0.003 | 0.002 | 0.997 ± 0.002 | 67 | 1.000 | 68 |
| mobbl-000 | 0.000 | 0.000 | 0.998 ± 0.001 | 68 | 0.978 | 55 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0.0005 | 69 | 1.000 | 63 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.381 | 12 |
| aware-001 | 0.149 | 0.035 | 1 ± 0 | 70 | 0.495 | 18 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.413 | 13 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.442 | 14 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 1.000 | 68 |
| iproov-000 | 0.084 | 0.016 | 1 ± 0 | 70 | 0.377 | 11 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.773 | 39 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.989 | 60 |
| trueface-000 | 0.309 | 0.271 | 1 ± 0 | 70 | 1.000 | 68 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.500 | 19 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 70 | 0.788 | 40 |
| yoti-001 | 0.442 | 0.388 | 1 ± 0 | 70 | 0.628 | 27 |
| yoti-002 | 0.502 | 0.393 | 1 ± 0 | 70 | 0.600 | 26 |

**Table 34.** PA Type 8 - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| alice-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 2 |
| idemia-011 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 4 |
| idrnd-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 3 |
| idrnd-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 1 |
| hyperverge-002 | 0.000 | 0.000 | 0.001 ± 0.001 | 5 | 0.003 | 6 |
| kakao-001 | 0.000 | 0.000 | 0.001 ± 0.001 | 5 | 0.003 | 5 |
| iproov-001 | 0.000 | 0.000 | 0.003 ± 0.002 | 7 | 0.005 | 8 |
| meituan-001 | 0.000 | 0.000 | 0.004 ± 0.003 | 8 | 0.003 | 7 |
| stcon-000 | 0.000 | 0.000 | 0.008 ± 0.005 | 9 | 0.007 | 10 |
| hyperverge-001 | 0.000 | 0.000 | 0.008 ± 0.005 | 10 | 0.009 | 12 |
| intema-001 | 0.000 | 0.000 | 0.008 ± 0.005 | 10 | 0.010 | 14 |
| kakao-000 | 0.000 | 0.000 | 0.009 ± 0.005 | 12 | 0.005 | 9 |
| innovatrics-001 | 0.000 | 0.000 | 0.01 ± 0.005 | 13 | 0.009 | 13 |
| saffe-002 | 0.000 | 0.000 | 0.01 ± 0.005 | 13 | 0.008 | 11 |
| jcv-001 | 0.004 | 0.000 | 0.012 ± 0.006 | 15 | 0.010 | 15 |
| stcon-001 | 0.000 | 0.000 | 0.015 ± 0.006 | 16 | 0.019 | 21 |
| cyberlink-002 | 0.000 | 0.000 | 0.016 ± 0.007 | 17 | 0.016 | 20 |
| saffe-001 | 0.000 | 0.000 | 0.016 ± 0.006 | 17 | 0.024 | 26 |
| onfido-001 | 0.000 | 0.000 | 0.017 ± 0.007 | 19 | 0.020 | 24 |
| mbsolutions-001 | 0.075 | 0.007 | 0.018 ± 0.007 | 20 | 0.026 | 27 |
| meituan-000 | 0.000 | 0.000 | 0.019 ± 0.007 | 21 | 0.099 | 37 |
| jcv-002 | 0.004 | 0.000 | 0.021 ± 0.007 | 22 | 0.014 | 18 |
| onfido-000 | 0.000 | 0.000 | 0.024 ± 0.008 | 23 | 0.019 | 21 |
| intema-000 | 0.000 | 0.000 | 0.025 ± 0.008 | 24 | 0.045 | 30 |
| incode-001 | 0.000 | 0.000 | 0.03 ± 0.01 | 25 | 0.021 | 25 |
| cyberlink-001 | 0.000 | 0.000 | 0.04 ± 0.01 | 26 | 0.040 | 29 |
| aware-002 | 0.000 | 0.000 | 0.08 ± 0.01 | 27 | 0.073 | 33 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.09 ± 0.02 | 28 | 0.126 | 39 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.1 ± 0.02 | 29 | 0.070 | 32 |
| neurotechnology-000 | 0.000 | 0.000 | 0.1 ± 0.02 | 30 | 0.095 | 36 |
| mbsolutions-000 | 0.000 | 0.000 | 0.1 ± 0.02 | 31 | 0.229 | 46 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.12 ± 0.02 | 32 | 0.115 | 38 |
| vida-002 | 0.000 | 0.000 | 0.12 ± 0.02 | 33 | 0.062 | 31 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.15 ± 0.02 | 34 | 0.141 | 41 |
| incode-000 | 0.000 | 0.000 | 0.19 ± 0.02 | 35 | 0.085 | 34 |
| iidentifii-000 | 0.000 | 0.000 | 0.2 ± 0.02 | 36 | 0.151 | 43 |
| idemia-010 | 0.000 | 0.000 | 0.22 ± 0.02 | 37 | 0.030 | 28 |
| verigram-001 | 0.000 | 0.000 | 0.28 ± 0.02 | 38 | 0.141 | 41 |
| rankone-000 | 0.000 | 0.000 | 0.34 ± 0.02 | 39 | 0.574 | 55 |
| pxl-001 | 0.000 | 0.000 | 0.37 ± 0.02 | 40 | 0.408 | 50 |
| rankone-001 | 0.000 | 0.000 | 0.39 ± 0.03 | 41 | 0.281 | 48 |

**Table 34.** PA Type 8 - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| nsensekorea-001 | 0.000 | 0.000 | 0.41 ± 0.03 | 42 | 0.863 | 71 |
| nsensekorea-000 | 0.000 | 0.000 | 0.41 ± 0.03 | 43 | 0.853 | 69 |
| innovatrics-002 | 0.000 | 0.000 | 0.43 ± 0.03 | 44 | 0.501 | 53 |
| veridas-001 | 0.000 | 0.000 | 0.45 ± 0.03 | 45 | 0.628 | 57 |
| facedirect-002 | 0.000 | 0.000 | 0.47 ± 0.03 | 46 | 1.000 | 77 |
| vida-001 | 0.000 | 0.000 | 0.48 ± 0.03 | 47 | 0.501 | 54 |
| techsign-001 | 0.007 | 0.007 | 0.53 ± 0.03 | 48 | 0.669 | 58 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.6 ± 0.03 | 49 | 0.806 | 65 |
| yoonik-002 | 0.000 | 0.000 | 0.6 ± 0.03 | 50 | 0.237 | 47 |
| veridas-002 | 0.000 | 0.000 | 0.62 ± 0.03 | 51 | 0.903 | 74 |
| mobbl-000 | 0.000 | 0.000 | 0.68 ± 0.02 | 52 | 0.745 | 62 |
| visteam-002 | 0.000 | 0.000 | 0.71 ± 0.02 | 53 | 1.000 | 77 |
| techsign-000 | 0.000 | 0.000 | 0.72 ± 0.02 | 54 | 0.587 | 56 |
| verigram-000 | 0.000 | 0.000 | 0.72 ± 0.02 | 55 | 0.128 | 40 |
| griaule-001 | 0.000 | 0.000 | 0.75 ± 0.02 | 56 | 1.000 | 77 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.79 ± 0.02 | 57 | 0.883 | 72 |
| facedirect-001 | 0.000 | 0.000 | 0.86 ± 0.02 | 58 | 0.956 | 76 |
| mobbl-001 | 0.000 | 0.000 | 0.86 ± 0.02 | 59 | 0.834 | 68 |
| biocube-002 | 0.000 | 0.000 | 0.88 ± 0.02 | 60 | 0.834 | 67 |
| cubox-001 | 0.000 | 0.000 | 0.88 ± 0.02 | 61 | 0.893 | 73 |
| biocube-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 62 | 0.779 | 63 |
| cubox-000 | 0.000 | 0.000 | 0.9 ± 0.02 | 63 | 0.806 | 66 |
| id3-001 | 0.000 | 0.000 | 0.92 ± 0.01 | 64 | 0.861 | 70 |
| visteam-001 | 0.000 | 0.000 | 0.92 ± 0.01 | 65 | 0.934 | 75 |
| spooff-000 | 0.000 | 0.000 | 0.96 ± 0.01 | 66 | 0.429 | 51 |
| tech5-001 | 0.001 | 0.002 | 0.999 ± 0.001 | 67 | 1.000 | 77 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 1.000 | 77 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.015 | 19 |
| aware-001 | 0.114 | 0.035 | 1 ± 0 | 68 | 0.086 | 35 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.011 | 16 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.012 | 17 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.468 | 52 |
| iproov-000 | 0.103 | 0.016 | 1 ± 0 | 68 | 0.020 | 23 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.224 | 45 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.696 | 60 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 1.000 | 77 |
| trueface-000 | 0.308 | 0.271 | 1 ± 0 | 68 | 0.382 | 49 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.678 | 59 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.193 | 44 |
| yoti-001 | 0.462 | 0.388 | 1 ± 0 | 68 | 0.720 | 61 |
| yoti-002 | 0.450 | 0.393 | 1 ± 0 | 68 | 0.788 | 64 |

**Table 35.** PA Type 8 (zoomed) - Use Case: detectImpersonationPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| idrnd-001 | 0.000 | 0.000 | 0.005 ± 0.004 | 1 | 0.006 | 1 |
| idrnd-000 | 0.000 | 0.000 | 0.011 ± 0.005 | 2 | 0.010 | 2 |
| stcon-000 | 0.000 | 0.000 | 0.018 ± 0.007 | 3 | 0.016 | 3 |
| idemia-011 | 0.000 | 0.000 | 0.028 ± 0.009 | 4 | 0.026 | 5 |
| kakao-001 | 0.000 | 0.000 | 0.031 ± 0.009 | 5 | 0.026 | 4 |
| iproov-001 | 0.000 | 0.000 | 0.04 ± 0.01 | 6 | 0.047 | 10 |
| jcv-001 | 0.007 | 0.000 | 0.05 ± 0.01 | 7 | 0.044 | 7 |
| stcon-001 | 0.000 | 0.000 | 0.06 ± 0.01 | 8 | 0.091 | 13 |
| onfido-001 | 0.003 | 0.000 | 0.06 ± 0.01 | 9 | 0.096 | 14 |
| kakao-000 | 0.000 | 0.000 | 0.06 ± 0.01 | 10 | 0.089 | 12 |
| onfido-000 | 0.003 | 0.000 | 0.07 ± 0.01 | 11 | 0.219 | 19 |
| meituan-001 | 0.000 | 0.000 | 0.07 ± 0.01 | 12 | 0.045 | 8 |
| jcv-002 | 0.007 | 0.000 | 0.07 ± 0.01 | 13 | 0.039 | 6 |
| kasikornlabs-000 | 0.001 | 0.000 | 0.12 ± 0.02 | 14 | 0.574 | 44 |
| saffe-002 | 0.000 | 0.000 | 0.12 ± 0.02 | 14 | 0.272 | 24 |
| intema-000 | 0.000 | 0.000 | 0.14 ± 0.02 | 16 | 0.304 | 30 |
| incode-001 | 0.000 | 0.000 | 0.14 ± 0.02 | 17 | 0.193 | 18 |
| mbsolutions-001 | 0.079 | 0.007 | 0.15 ± 0.02 | 18 | 0.628 | 50 |
| hyperverge-002 | 0.000 | 0.000 | 0.15 ± 0.02 | 19 | 0.989 | 73 |
| saffe-001 | 0.000 | 0.000 | 0.17 ± 0.02 | 20 | 0.308 | 31 |
| intema-001 | 0.000 | 0.000 | 0.17 ± 0.02 | 21 | 0.284 | 28 |
| pxl-001 | 0.002 | 0.000 | 0.19 ± 0.02 | 22 | 0.275 | 27 |
| alice-001 | 0.000 | 0.000 | 0.22 ± 0.02 | 23 | 1.000 | 74 |
| kasikornlabs-001 | 0.001 | 0.000 | 0.22 ± 0.02 | 23 | 0.628 | 48 |
| idemia-010 | 0.000 | 0.000 | 0.23 ± 0.02 | 25 | 0.130 | 15 |
| vida-002 | 0.001 | 0.000 | 0.23 ± 0.02 | 26 | 0.628 | 48 |
| hyperverge-001 | 0.000 | 0.000 | 0.23 ± 0.02 | 27 | 1.000 | 74 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.26 ± 0.02 | 28 | 0.251 | 23 |
| veridas-001 | 0.001 | 0.000 | 0.27 ± 0.02 | 29 | 0.484 | 37 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.27 ± 0.02 | 30 | 0.272 | 24 |
| iidentifii-000 | 0.000 | 0.000 | 0.28 ± 0.02 | 31 | 0.542 | 42 |
| facedirect-002 | 0.000 | 0.000 | 0.3 ± 0.02 | 32 | 1.000 | 74 |
| neurotechnology-000 | 0.000 | 0.000 | 0.3 ± 0.02 | 33 | 1.000 | 74 |
| aware-002 | 0.000 | 0.000 | 0.31 ± 0.02 | 34 | 0.308 | 31 |
| incode-000 | 0.000 | 0.000 | 0.31 ± 0.02 | 34 | 0.720 | 55 |
| rankone-000 | 0.000 | 0.000 | 0.33 ± 0.02 | 36 | 0.561 | 43 |
| meituan-000 | 0.000 | 0.000 | 0.34 ± 0.02 | 37 | 0.665 | 51 |
| innovatrics-001 | 0.000 | 0.000 | 0.35 ± 0.02 | 38 | 0.245 | 21 |
| rankone-001 | 0.000 | 0.000 | 0.37 ± 0.03 | 39 | 0.284 | 28 |
| yoonik-002 | 0.000 | 0.000 | 0.37 ± 0.03 | 40 | 0.341 | 33 |
| innovatrics-002 | 0.000 | 0.000 | 0.4 ± 0.03 | 41 | 0.408 | 35 |

**Table 35.** PA Type 8 (zoomed) - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| mbsolutions-000 | 0.000 | 0.000 | 0.42 ± 0.03 | 42 | 0.686 | 52 |
| veridas-002 | 0.001 | 0.000 | 0.43 ± 0.03 | 43 | 0.883 | 64 |
| griaule-001 | 0.000 | 0.000 | 0.55 ± 0.03 | 44 | 0.490 | 38 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.59 ± 0.03 | 45 | 0.902 | 67 |
| cyberlink-002 | 0.000 | 0.000 | 0.6 ± 0.02 | 46 | 1.000 | 74 |
| vida-001 | 0.001 | 0.000 | 0.61 ± 0.03 | 47 | 0.736 | 56 |
| verigram-001 | 0.000 | 0.000 | 0.63 ± 0.03 | 48 | 0.614 | 46 |
| visteam-002 | 0.000 | 0.000 | 0.66 ± 0.02 | 49 | 1.000 | 74 |
| cyberlink-001 | 0.000 | 0.000 | 0.7 ± 0.02 | 50 | 0.761 | 59 |
| mobbl-000 | 0.000 | 0.000 | 0.75 ± 0.02 | 51 | 0.580 | 45 |
| techsign-001 | 0.000 | 0.007 | 0.79 ± 0.02 | 52 | 0.535 | 41 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.81 ± 0.02 | 53 | 0.893 | 65 |
| techsign-000 | 0.000 | 0.000 | 0.81 ± 0.02 | 53 | 0.779 | 61 |
| facedirect-001 | 0.000 | 0.000 | 0.82 ± 0.02 | 55 | 0.913 | 68 |
| mobbl-001 | 0.000 | 0.000 | 0.87 ± 0.02 | 56 | 0.770 | 60 |
| visteam-001 | 0.000 | 0.000 | 0.87 ± 0.02 | 57 | 0.934 | 69 |
| biocube-002 | 0.000 | 0.000 | 0.88 ± 0.02 | 58 | 0.501 | 39 |
| nsensekorea-001 | 0.000 | 0.000 | 0.89 ± 0.02 | 59 | 0.945 | 71 |
| nsensekorea-000 | 0.000 | 0.000 | 0.89 ± 0.02 | 60 | 0.945 | 72 |
| cubox-000 | 0.000 | 0.000 | 0.89 ± 0.02 | 61 | 0.806 | 62 |
| biocube-001 | 0.000 | 0.000 | 0.91 ± 0.01 | 62 | 0.530 | 40 |
| cubox-001 | 0.000 | 0.000 | 0.94 ± 0.01 | 63 | 0.893 | 65 |
| spooff-000 | 0.000 | 0.000 | 0.94 ± 0.01 | 64 | 0.936 | 70 |
| verigram-000 | 0.000 | 0.000 | 0.984 ± 0.007 | 65 | 0.462 | 36 |
| tech5-001 | 0.007 | 0.002 | 0.993 ± 0.005 | 66 | 1.000 | 74 |
| papago-001 | 0.000 | 0.000 | 0.999 ± 0.002 | 67 | 0.696 | 54 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 1.000 | 74 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.813 | 63 |
| aware-001 | 0.117 | 0.035 | 1 ± 0 | 68 | 0.248 | 22 |
| facephi-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.146 | 16 |
| facephi-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.079 | 11 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.386 | 34 |
| id3-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.760 | 58 |
| iproov-000 | 0.225 | 0.016 | 1 ± 0 | 68 | 0.046 | 9 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.224 | 20 |
| pxl-000 | 0.002 | 0.000 | 1 ± 0 | 68 | 1.000 | 74 |
| trueface-000 | 1.000 | 0.271 | 1 ± 0 | 68 | 0.272 | 24 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.628 | 47 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 68 | 0.179 | 17 |
| yoti-001 | 0.357 | 0.388 | 1 ± 0 | 68 | 0.688 | 53 |

**Table 35.** PA Type 8 (zoomed) - Use Case: detectImpersonationPA - Media Type: stills *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| yoti-002 | 0.399 | 0.393 | 1 ± 0 | 68 | 0.745 | 57 |

**Table 36.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| cyberlink-002 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.006 | 1 |
| kakao-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.006 | 1 |
| cyberlink-001 | 0.000 | 0.000 | 0.1 ± 0.1 | 3 | 0.011 | 4 |
| kakao-000 | 0.000 | 0.000 | 0.1 ± 0.1 | 3 | 0.041 | 11 |
| stcon-001 | 0.000 | 0.000 | 0.1 ± 0.1 | 3 | 0.009 | 3 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.1 ± 0.1 | 3 | 0.015 | 6 |
| idrnd-001 | 0.000 | 0.000 | 0.1 ± 0.2 | 7 | 0.033 | 10 |
| iproov-001 | 0.000 | 0.000 | 0.1 ± 0.2 | 7 | 0.071 | 15 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.1 ± 0.2 | 7 | 0.024 | 8 |
| stcon-000 | 0.000 | 0.000 | 0.1 ± 0.2 | 7 | 0.188 | 28 |
| idrnd-000 | 0.000 | 0.000 | 0.2 ± 0.2 | 11 | 0.087 | 18 |
| veridas-001 | 0.000 | 0.000 | 0.2 ± 0.2 | 11 | 0.061 | 12 |
| hyperverge-001 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.149 | 24 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.061 | 12 |
| alice-001 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.461 | 44 |
| hyperverge-002 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.022 | 7 |
| veridas-002 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.011 | 4 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.3 ± 0.2 | 13 | 0.128 | 21 |
| neurotechnology-000 | 0.000 | 0.000 | 0.4 ± 0.2 | 19 | 0.099 | 19 |
| iidentifii-000 | 0.000 | 0.000 | 0.4 ± 0.3 | 20 | 0.171 | 25 |
| facephi-000 | 0.000 | 0.000 | 0.5 ± 0.3 | 21 | 0.262 | 35 |
| onfido-000 | 0.000 | 0.000 | 0.5 ± 0.3 | 21 | 0.788 | 68 |
| meituan-000 | 0.000 | 0.000 | 0.6 ± 0.2 | 23 | 0.403 | 42 |
| innovatrics-002 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.608 | 54 |
| rankone-000 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.080 | 17 |
| vida-001 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.844 | 73 |
| vida-002 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.134 | 23 |
| visteam-002 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.065 | 14 |
| meituan-001 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.191 | 29 |
| onfido-001 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.753 | 66 |
| techsign-000 | 0.000 | 0.000 | 0.7 ± 0.2 | 24 | 0.100 | 20 |
| cubox-000 | 0.000 | 0.000 | 0.8 ± 0.2 | 32 | 0.489 | 46 |
| facedirect-001 | 0.000 | 0.000 | 0.8 ± 0.2 | 32 | 0.770 | 67 |
| id3-001 | 0.000 | 0.000 | 0.8 ± 0.2 | 32 | 0.221 | 33 |
| idemia-010 | 0.000 | 0.000 | 0.8 ± 0.2 | 32 | 0.184 | 27 |
| griaule-001 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.214 | 31 |
| idvisioncenter-001 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.524 | 48 |
| incode-001 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.281 | 36 |
| intema-000 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.636 | 56 |
| pxl-001 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.130 | 22 |
| saffe-002 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.658 | 57 |

**Table 36.** PA Type 1 - Use Case: detectImpersonationPA - Media Type: videos *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| techsign-001 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.325 | 39 |
| verigram-000 | 0.000 | 0.000 | 0.9 ± 0.1 | 36 | 0.719 | 63 |
| biocube-001 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.483 | 45 |
| biocube-002 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.823 | 71 |
| facephi-001 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.664 | 58 |
| idemia-011 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.883 | 76 |
| innovatrics-001 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.680 | 61 |
| intema-001 | 0.000 | 0.000 | 0.9 ± 0.2 | 44 | 0.621 | 55 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 1.000 | 81 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.177 | 26 |
| aware-001 | 0.000 | 0.004 | 1 ± 0 | 50 | 0.072 | 16 |
| aware-002 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.600 | 53 |
| cubox-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.305 | 37 |
| facedirect-002 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.991 | 78 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.665 | 59 |
| idvisioncenter-002 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.554 | 50 |
| incode-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.309 | 38 |
| iproov-000 | 0.000 | 0.017 | 1 ± 0 | 50 | 0.030 | 9 |
| jcv-001 | 0.000 | 0.033 | 1 ± 0 | 50 | 0.513 | 47 |
| jcv-002 | 0.000 | 0.013 | 1 ± 0 | 50 | 0.524 | 48 |
| mbsolutions-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.872 | 74 |
| mbsolutions-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.872 | 74 |
| mobbl-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.892 | 77 |
| mobbl-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.574 | 52 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.428 | 43 |
| nsensekorea-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.743 | 65 |
| nsensekorea-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.742 | 64 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 1.000 | 81 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.998 | 79 |
| rankone-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.193 | 30 |
| saffe-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.797 | 70 |
| spooff-000 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.788 | 68 |
| tech5-001 | 0.000 | 0.022 | 1 ± 0 | 50 | 0.998 | 79 |
| trueface-000 | 0.267 | 0.803 | 1 ± 0 | 50 | 0.833 | 72 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.567 | 51 |
| verigram-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.673 | 60 |
| visteam-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.712 | 62 |
| yoonik-001 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.387 | 40 |
| yoonik-002 | 0.000 | 0.000 | 1 ± 0 | 50 | 0.390 | 41 |
| yoti-001 | 0.400 | 0.160 | 1 ± 0 | 50 | 0.219 | 32 |
| yoti-002 | 0.400 | 0.158 | 1 ± 0 | 50 | 0.240 | 34 |

**Table 37.** PA Type 3 - Use Case: detectImpersonationPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| alice-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| cyberlink-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| cyberlink-002 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| idrnd-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| idrnd-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| iidentifii-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| incode-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| innovatrics-002 | 0 | 0.000 | 0 ± 0 | 1 | 0.006 | 11 |
| iproov-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| stcon-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| stcon-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| facephi-000 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.022 | 18 |
| innovatrics-001 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.188 | 39 |
| kakao-001 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.015 | 14 |
| kasikornlabs-000 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.013 | 12 |
| kasikornlabs-001 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.059 | 29 |
| onfido-000 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.013 | 12 |
| onfido-001 | 0 | 0.000 | 0.1 ± 0.2 | 12 | 0.035 | 20 |
| facephi-001 | 0 | 0.000 | 0.2 ± 0.2 | 19 | 0.046 | 25 |
| rankone-000 | 0 | 0.000 | 0.2 ± 0.2 | 19 | 0.020 | 17 |
| aware-002 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.084 | 32 |
| idemia-011 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.041 | 22 |
| incode-000 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.033 | 19 |
| intema-001 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.119 | 36 |
| mbsolutions-001 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.658 | 54 |
| meituan-000 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.797 | 62 |
| veridas-002 | 0 | 0.000 | 0.3 ± 0.3 | 21 | 0.043 | 23 |
| intema-000 | 0 | 0.000 | 0.4 ± 0.3 | 28 | 0.374 | 49 |
| neurotechnology-000 | 0 | 0.000 | 0.4 ± 0.3 | 28 | 0.139 | 38 |
| saffe-002 | 0 | 0.000 | 0.4 ± 0.3 | 28 | 0.281 | 47 |
| veridas-001 | 0 | 0.000 | 0.4 ± 0.3 | 28 | 0.128 | 37 |
| vida-002 | 0 | 0.000 | 0.4 ± 0.3 | 28 | 0.232 | 45 |
| griaule-000 | 0 | 0.000 | 0.5 ± 0.3 | 33 | 0.212 | 43 |
| hyperverge-001 | 0 | 0.000 | 0.5 ± 0.3 | 33 | 0.112 | 34 |
| kakao-000 | 0 | 0.000 | 0.5 ± 0.3 | 33 | 0.046 | 25 |
| mbsolutions-000 | 0 | 0.000 | 0.5 ± 0.3 | 33 | 0.658 | 54 |
| saffe-001 | 0 | 0.000 | 0.5 ± 0.3 | 33 | 0.214 | 44 |
| idvisioncenter-001 | 0 | 0.000 | 0.6 ± 0.3 | 38 | 0.901 | 69 |
| vida-001 | 0 | 0.000 | 0.6 ± 0.3 | 38 | 0.361 | 48 |
| facedirect-001 | 0 | 0.000 | 0.7 ± 0.3 | 40 | 0.045 | 24 |
| meituan-001 | 0 | 0.000 | 0.7 ± 0.3 | 40 | 0.050 | 27 |

**Table 37.** PA Type 3 - Use Case: detectImpersonationPA - Media Type: videos *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| rankone-001 | 0 | 0.000 | 0.7 ± 0.3 | 40 | 0.037 | 21 |
| visteam-002 | 0 | 0.000 | 0.7 ± 0.3 | 40 | 0.058 | 28 |
| idemia-010 | 0 | 0.000 | 0.8 ± 0.2 | 44 | 0.117 | 35 |
| techsign-001 | 0 | 0.000 | 0.8 ± 0.2 | 44 | 0.104 | 33 |
| verihubs-inteligensia-000 | 0 | 0.000 | 0.8 ± 0.2 | 44 | 0.600 | 52 |
| biocube-001 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.797 | 62 |
| biocube-002 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.901 | 69 |
| griaule-001 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.203 | 42 |
| hyperverge-002 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.069 | 31 |
| id3-001 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.883 | 68 |
| idvisioncenter-002 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.688 | 57 |
| techsign-000 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.753 | 60 |
| verihubs-inteligensia-001 | 0 | 0.000 | 0.9 ± 0.2 | 47 | 0.266 | 46 |
| alchera-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.998 | 77 |
| alice-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.063 | 30 |
| aware-001 | 0 | 0.004 | 1 ± 0 | 55 | 0.017 | 15 |
| cubox-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.976 | 74 |
| cubox-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.998 | 77 |
| facedirect-002 | 0 | 0.000 | 1 ± 0 | 55 | 0.991 | 76 |
| iproov-000 | 0 | 0.017 | 1 ± 0 | 55 | 0.017 | 15 |
| jcv-001 | 0 | 0.033 | 1 ± 0 | 55 | 1.000 | 81 |
| jcv-002 | 0 | 0.013 | 1 ± 0 | 55 | 0.727 | 58 |
| mobbl-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.913 | 71 |
| mobbl-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.814 | 66 |
| neurotechnology-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.643 | 53 |
| nsensekorea-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.998 | 77 |
| nsensekorea-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.998 | 77 |
| papago-001 | 0 | 0.000 | 1 ± 0 | 55 | 1.000 | 81 |
| pxl-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.955 | 73 |
| pxl-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.680 | 56 |
| spooff-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.833 | 67 |
| tech5-001 | 0 | 0.022 | 1 ± 0 | 55 | 0.976 | 74 |
| trueface-000 | 1 | 0.803 | 1 ± 0 | 55 | 0.805 | 64 |
| uxlabs-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.561 | 51 |
| verigram-000 | 0 | 0.000 | 1 ± 0 | 55 | 0.805 | 64 |
| verigram-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.530 | 50 |
| visteam-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.924 | 72 |
| yoonik-001 | 0 | 0.000 | 1 ± 0 | 55 | 0.762 | 61 |
| yoonik-002 | 0 | 0.000 | 1 ± 0 | 55 | 0.743 | 59 |
| yoti-001 | 0 | 0.160 | 1 ± 0 | 55 | 0.191 | 41 |
| yoti-002 | 0 | 0.158 | 1 ± 0 | 55 | 0.188 | 39 |

**Table 38.** PA Type 8 - Use Case: detectImpersonationPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| alice-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| cyberlink-002 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.004 | 23 |
| facephi-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| facephi-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| griaule-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| hyperverge-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| hyperverge-002 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.006 | 26 |
| idemia-011 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| idrnd-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| idrnd-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| idvisioncenter-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.006 | 26 |
| iidentifii-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| intema-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| intema-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| iproov-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kasikornlabs-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kasikornlabs-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| mbsolutions-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.007 | 29 |
| mbsolutions-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| meituan-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| meituan-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| neurotechnology-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| onfido-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.004 | 23 |
| saffe-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| saffe-002 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| stcon-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| stcon-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| verigram-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.006 | 26 |
| vida-002 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.004 | 23 |
| cyberlink-001 | 0.000 | 0.000 | 0.02 ± 0.03 | 30 | 0.032 | 39 |
| incode-001 | 0.000 | 0.000 | 0.02 ± 0.03 | 30 | 0.019 | 34 |
| innovatrics-001 | 0.000 | 0.000 | 0.02 ± 0.03 | 30 | 0.022 | 37 |
| onfido-001 | 0.000 | 0.000 | 0.02 ± 0.03 | 30 | 0.011 | 31 |
| rankone-001 | 0.000 | 0.000 | 0.02 ± 0.03 | 30 | 0.009 | 30 |
| kakao-001 | 0.000 | 0.000 | 0.04 ± 0.05 | 35 | 0.052 | 43 |
| idemia-010 | 0.000 | 0.000 | 0.07 ± 0.06 | 36 | 0.048 | 42 |
| innovatrics-002 | 0.000 | 0.000 | 0.07 ± 0.06 | 36 | 0.019 | 34 |
| id3-001 | 0.000 | 0.000 | 0.11 ± 0.08 | 38 | 0.046 | 41 |
| kakao-000 | 0.000 | 0.000 | 0.11 ± 0.08 | 38 | 0.165 | 59 |
| incode-000 | 0.000 | 0.000 | 0.13 ± 0.08 | 40 | 0.015 | 32 |
| verigram-000 | 0.000 | 0.000 | 0.13 ± 0.09 | 41 | 0.052 | 43 |

**Table 38.** PA Type 8 - Use Case: detectImpersonationPA - Media Type: videos *(continued)*

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| techsign-001 | 0.000 | 0.000 | 0.2 ± 0.1 | 42 | 0.149 | 56 |
| verihubs-inteligensia-000 | 0.000 | 0.000 | 0.2 ± 0.1 | 42 | 0.262 | 65 |
| verihubs-inteligensia-001 | 0.000 | 0.000 | 0.2 ± 0.1 | 42 | 0.227 | 62 |
| yoonik-001 | 0.000 | 0.000 | 0.3 ± 0.1 | 45 | 0.084 | 50 |
| pxl-001 | 0.000 | 0.000 | 0.4 ± 0.1 | 46 | 0.078 | 48 |
| rankone-000 | 0.000 | 0.000 | 0.4 ± 0.1 | 46 | 0.024 | 38 |
| idvisioncenter-002 | 0.000 | 0.000 | 0.4 ± 0.1 | 46 | 0.045 | 40 |
| veridas-001 | 0.000 | 0.000 | 0.5 ± 0.1 | 49 | 0.067 | 47 |
| griaule-001 | 0.000 | 0.000 | 0.5 ± 0.1 | 49 | 0.104 | 54 |
| visteam-001 | 0.000 | 0.000 | 0.5 ± 0.1 | 49 | 0.574 | 72 |
| facedirect-002 | 0.000 | 0.000 | 0.6 ± 0.1 | 52 | 0.991 | 78 |
| facedirect-001 | 0.000 | 0.000 | 0.7 ± 0.1 | 53 | 0.987 | 77 |
| veridas-002 | 0.000 | 0.000 | 0.7 ± 0.1 | 53 | 0.086 | 51 |
| techsign-000 | 0.000 | 0.000 | 0.7 ± 0.1 | 53 | 0.082 | 49 |
| aware-002 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.309 | 67 |
| vida-001 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.234 | 63 |
| biocube-001 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.600 | 73 |
| biocube-002 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.554 | 71 |
| nsensekorea-000 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.409 | 69 |
| nsensekorea-001 | 0.000 | 0.000 | 0.8 ± 0.1 | 56 | 0.418 | 70 |
| mobbl-000 | 0.000 | 0.000 | 0.89 ± 0.08 | 62 | 0.892 | 76 |
| visteam-002 | 0.000 | 0.000 | 0.91 ± 0.08 | 63 | 0.257 | 64 |
| cubox-001 | 0.000 | 0.000 | 0.96 ± 0.05 | 64 | 0.385 | 68 |
| mobbl-001 | 0.000 | 0.000 | 0.96 ± 0.05 | 64 | 0.703 | 74 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 66 | 1.000 | 80 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.065 | 46 |
| aware-001 | 0.000 | 0.004 | 1 ± 0 | 66 | 0.143 | 55 |
| cubox-000 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.095 | 53 |
| iproov-000 | 0.000 | 0.017 | 1 ± 0 | 66 | 0.017 | 33 |
| jcv-001 | 0.037 | 0.033 | 1 ± 0 | 66 | 0.059 | 45 |
| jcv-002 | 0.019 | 0.013 | 1 ± 0 | 66 | 0.019 | 34 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.154 | 58 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 66 | 1.000 | 80 |
| pxl-000 | 0.000 | 0.000 | 1 ± 0 | 66 | 1.000 | 80 |
| spooff-000 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.307 | 66 |
| tech5-001 | 0.037 | 0.022 | 1 ± 0 | 66 | 0.998 | 79 |
| trueface-000 | 0.704 | 0.803 | 1 ± 0 | 66 | 0.805 | 75 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.093 | 52 |
| yoonik-002 | 0.000 | 0.000 | 1 ± 0 | 66 | 0.149 | 56 |
| yoti-001 | 0.037 | 0.160 | 1 ± 0 | 66 | 0.201 | 60 |
| yoti-002 | 0.037 | 0.158 | 1 ± 0 | 66 | 0.208 | 61 |

**Fig. 12.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

**Fig. 13.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

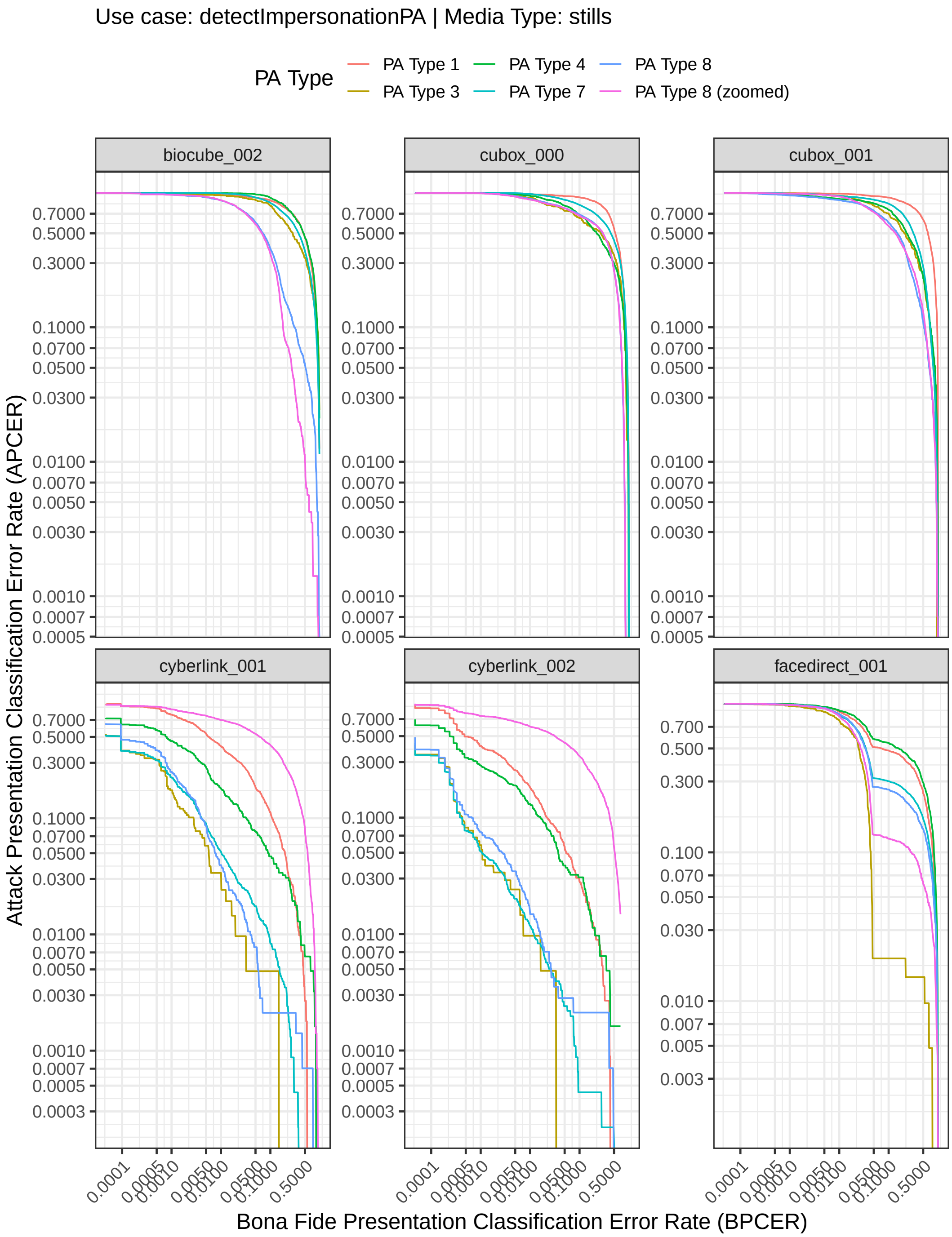


**Fig. 14.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

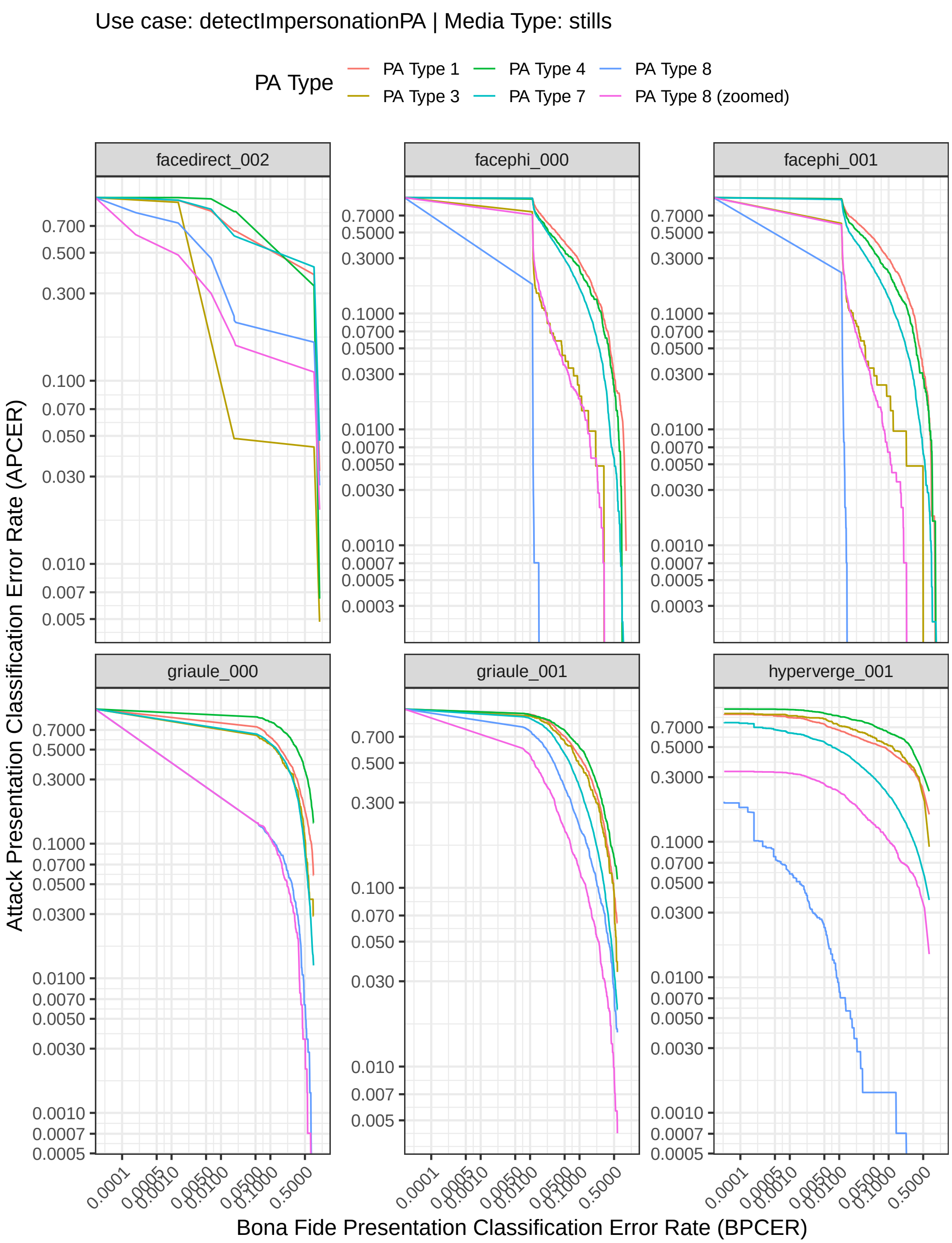


**Fig. 15.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

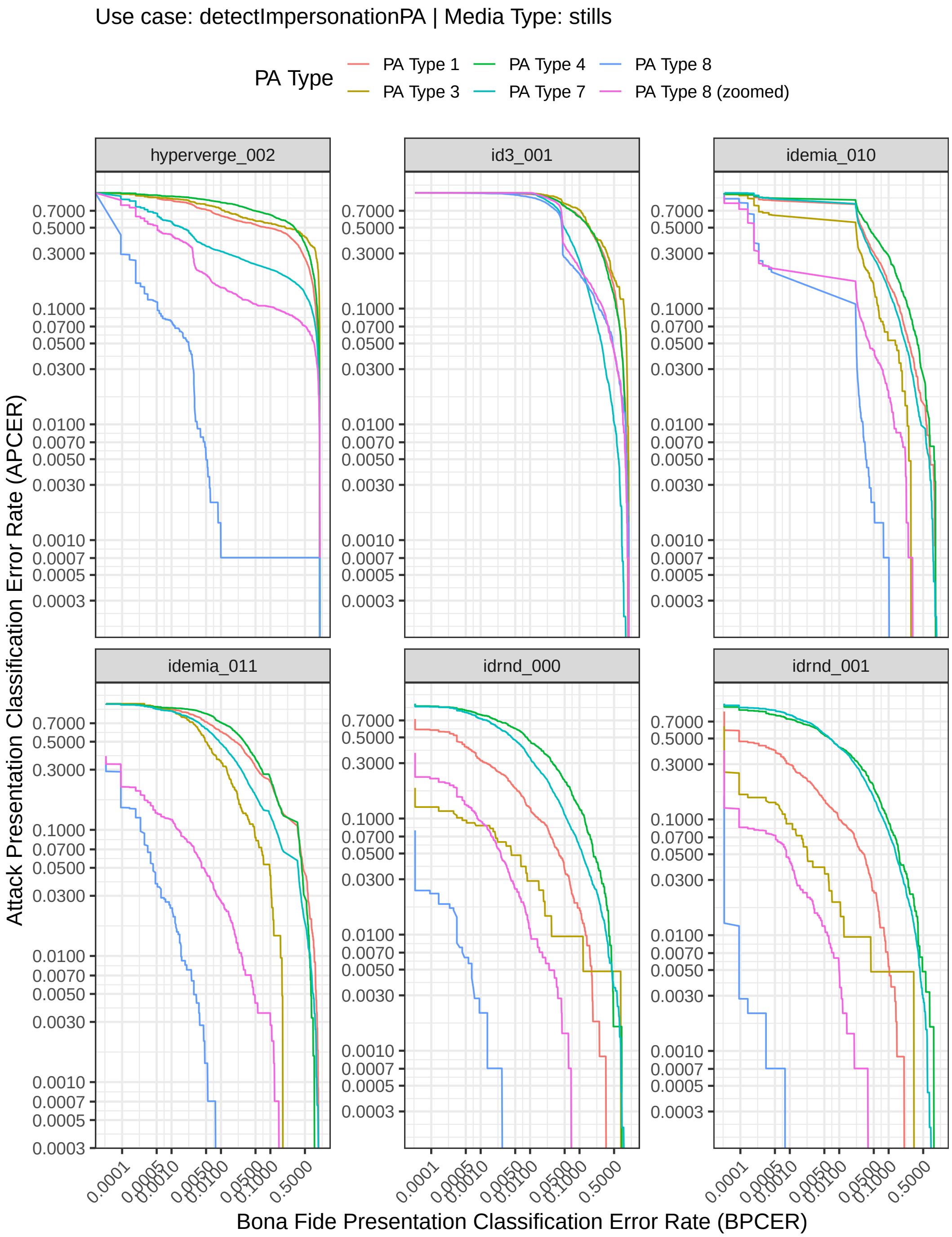


**Fig. 16.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

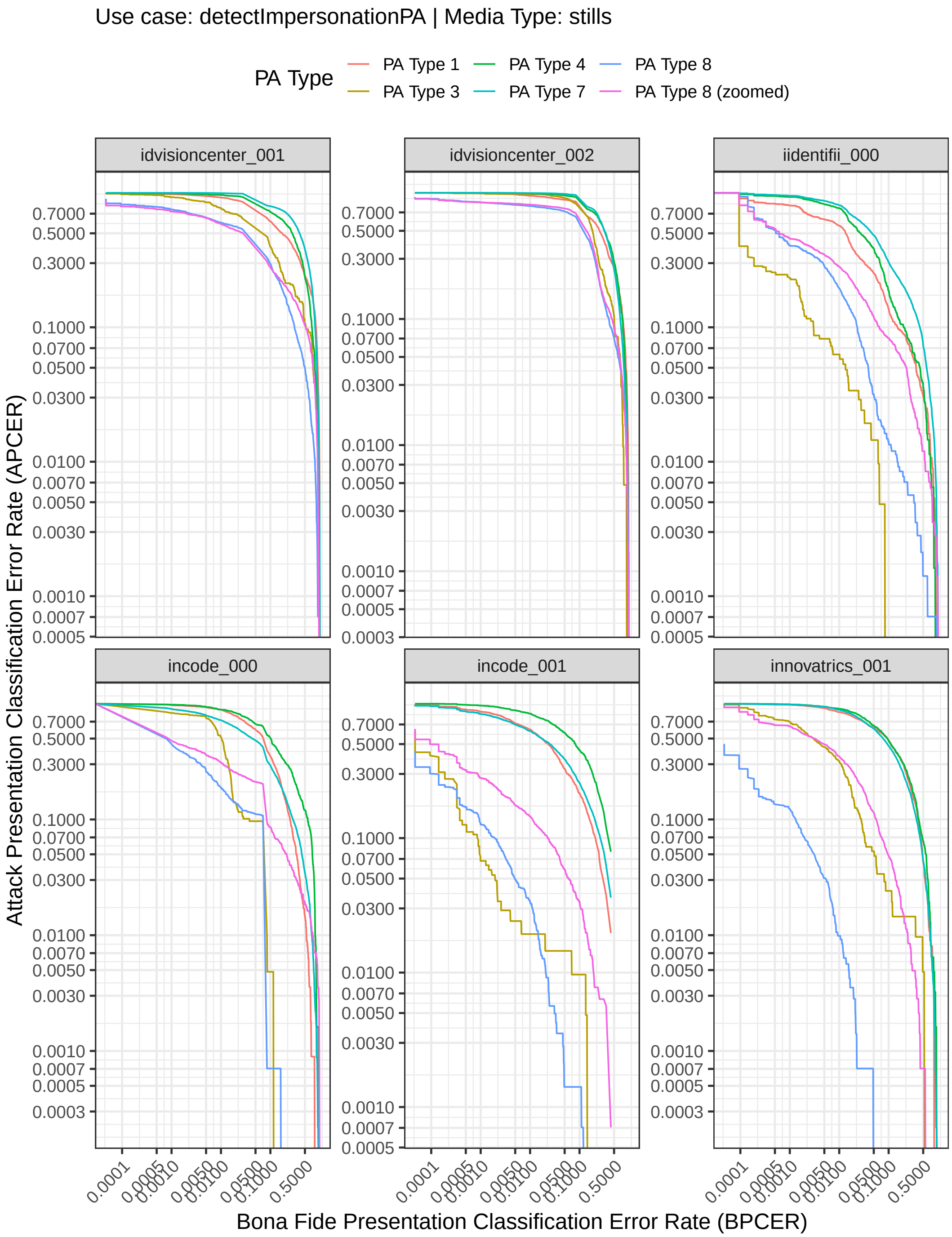


**Fig. 17.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

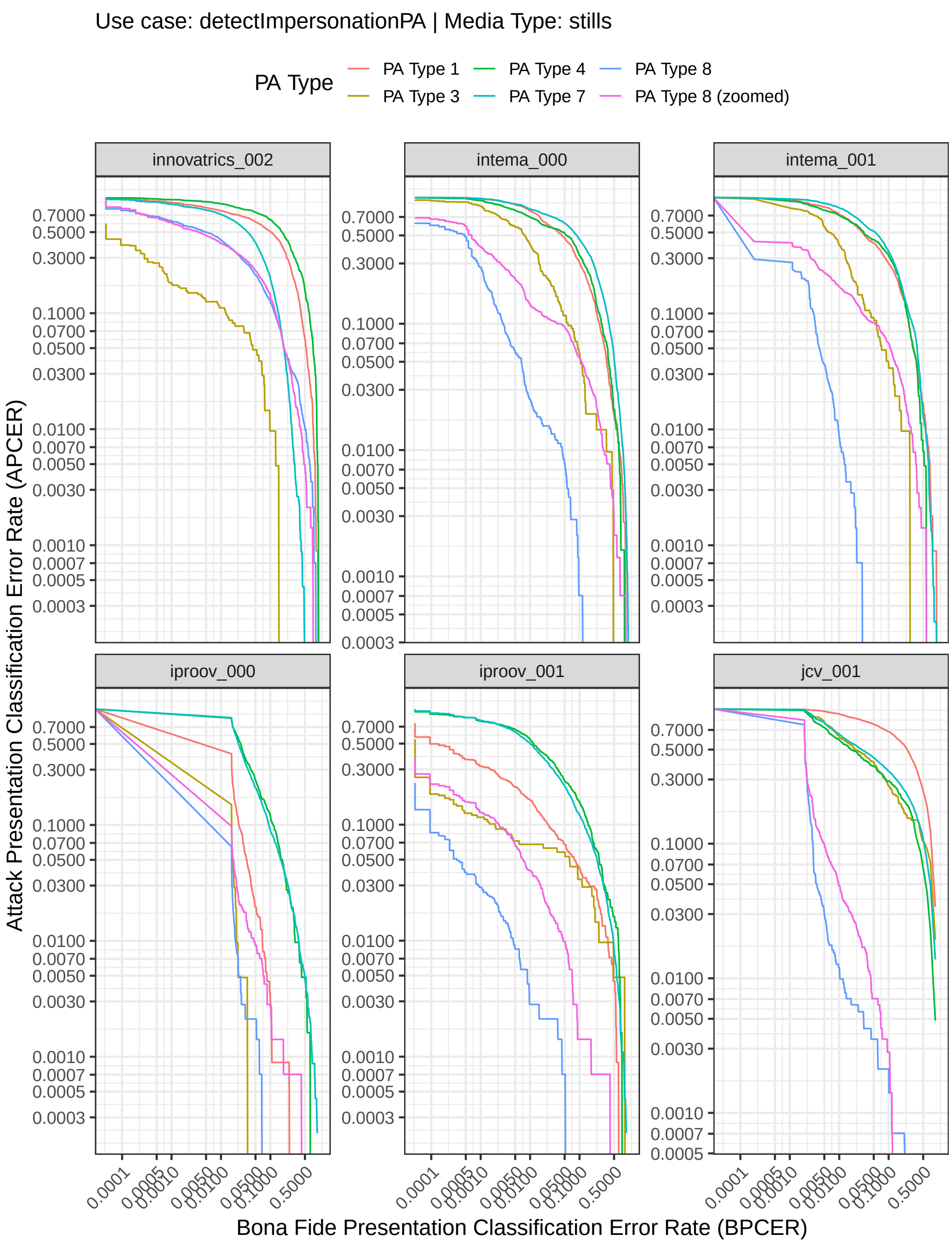


**Fig. 18.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

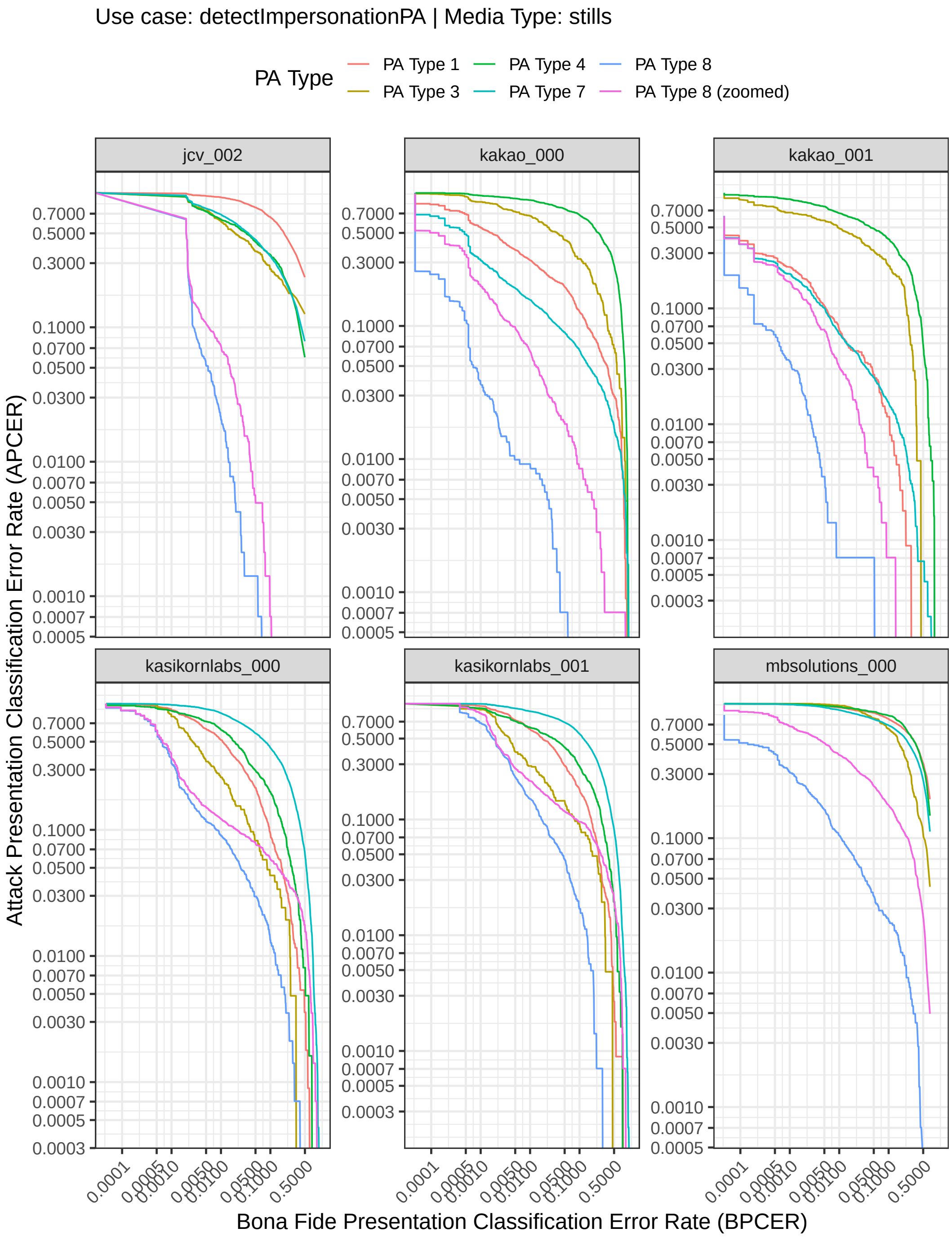


**Fig. 19.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

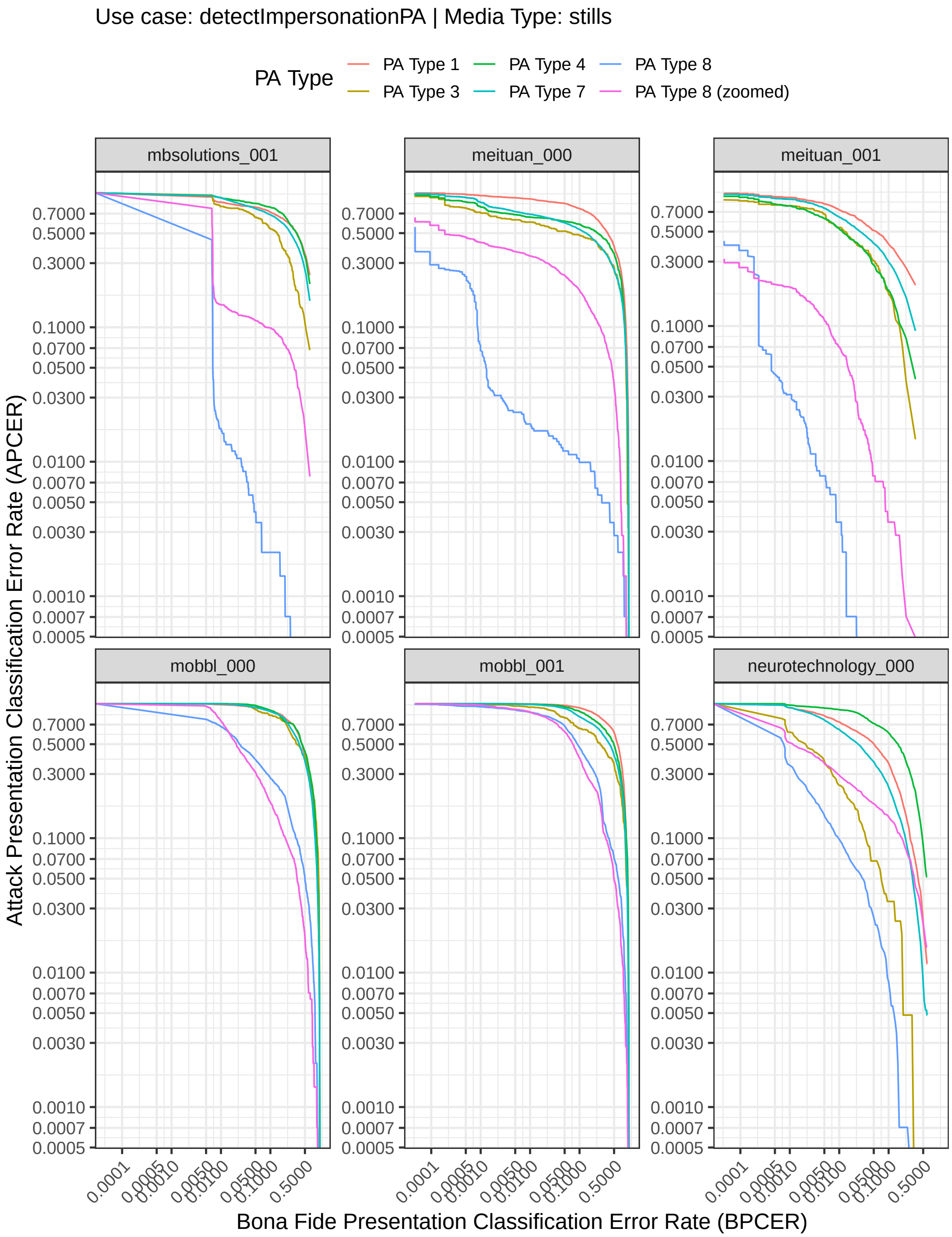


**Fig. 20.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

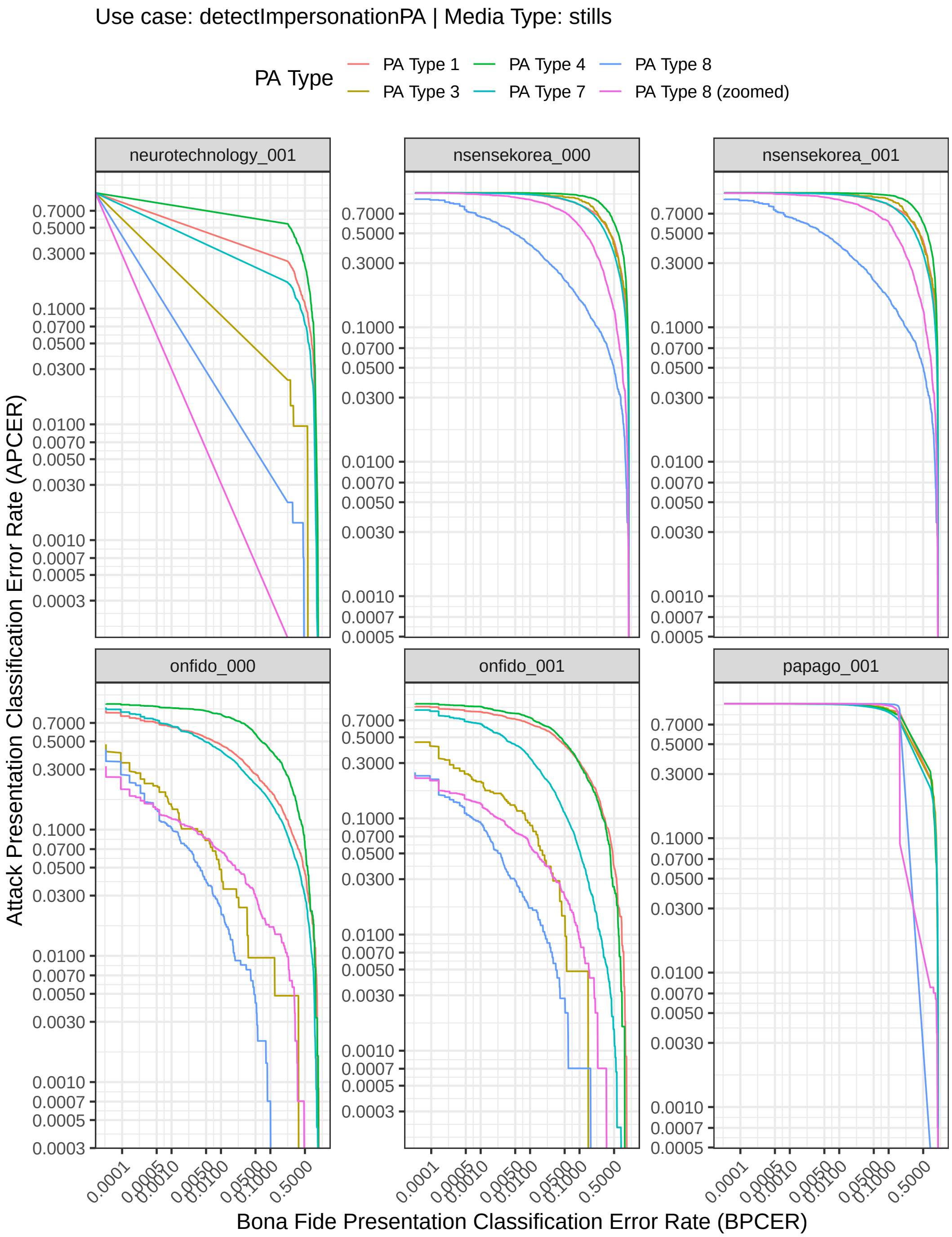


**Fig. 21.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

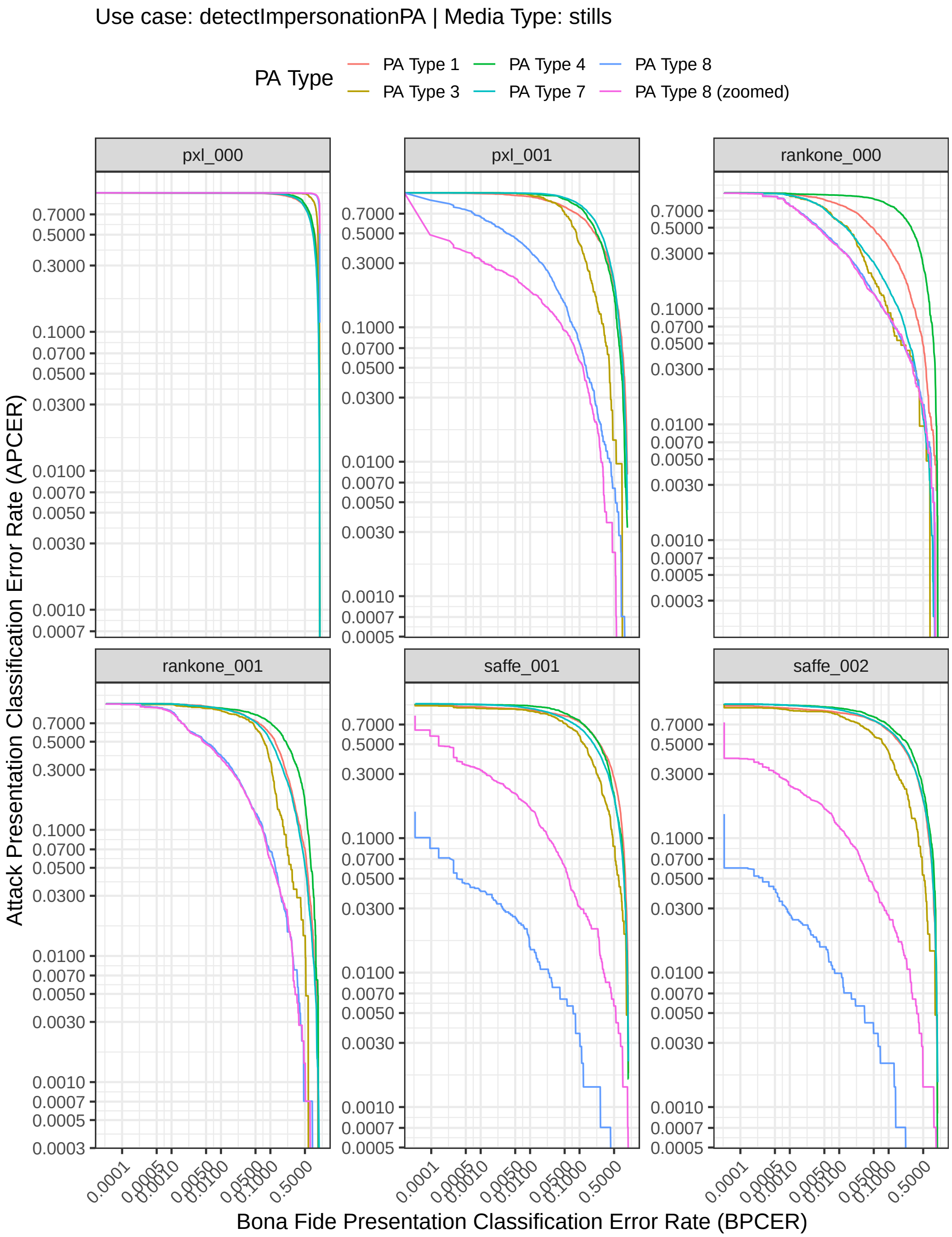


**Fig. 22.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

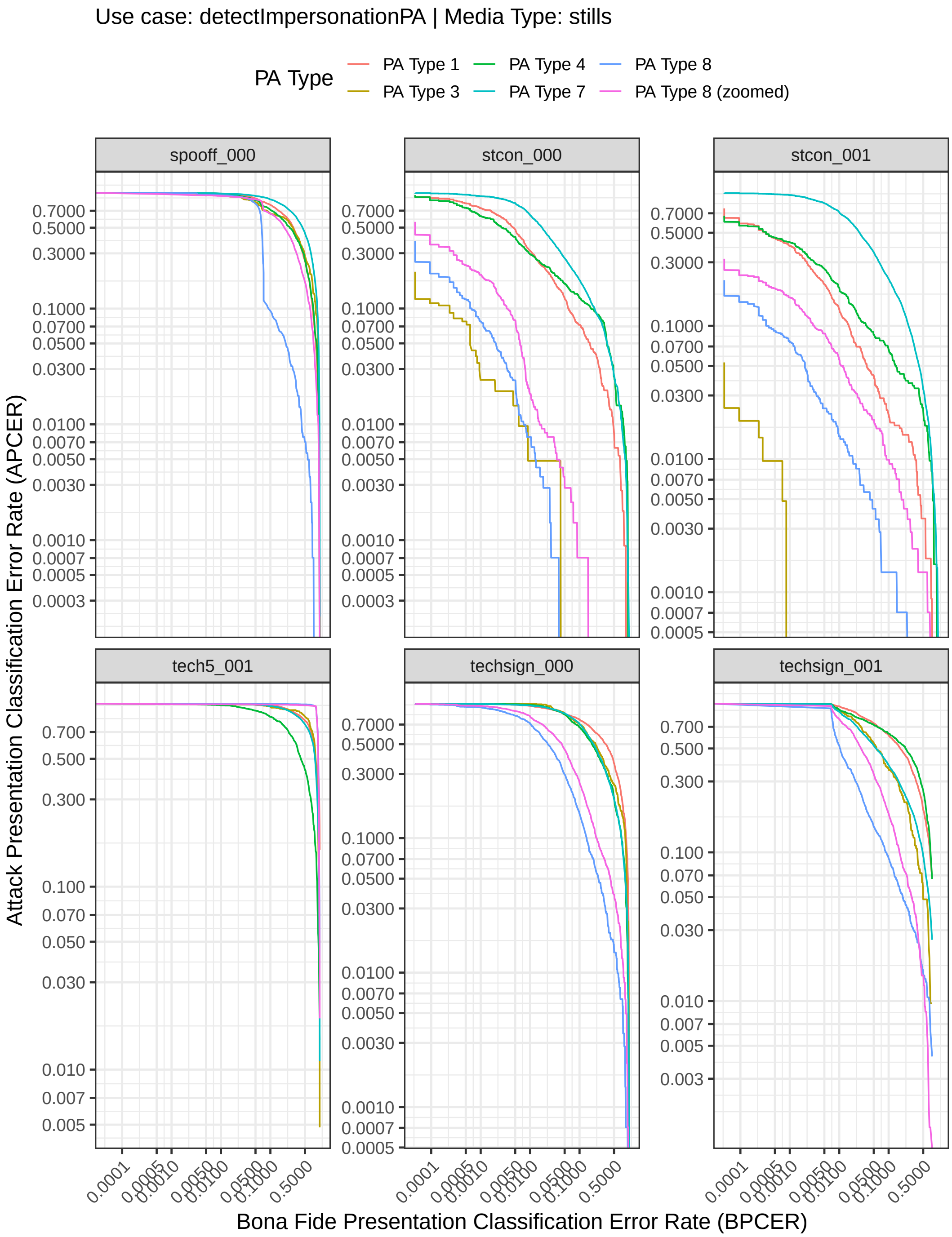


**Fig. 23.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

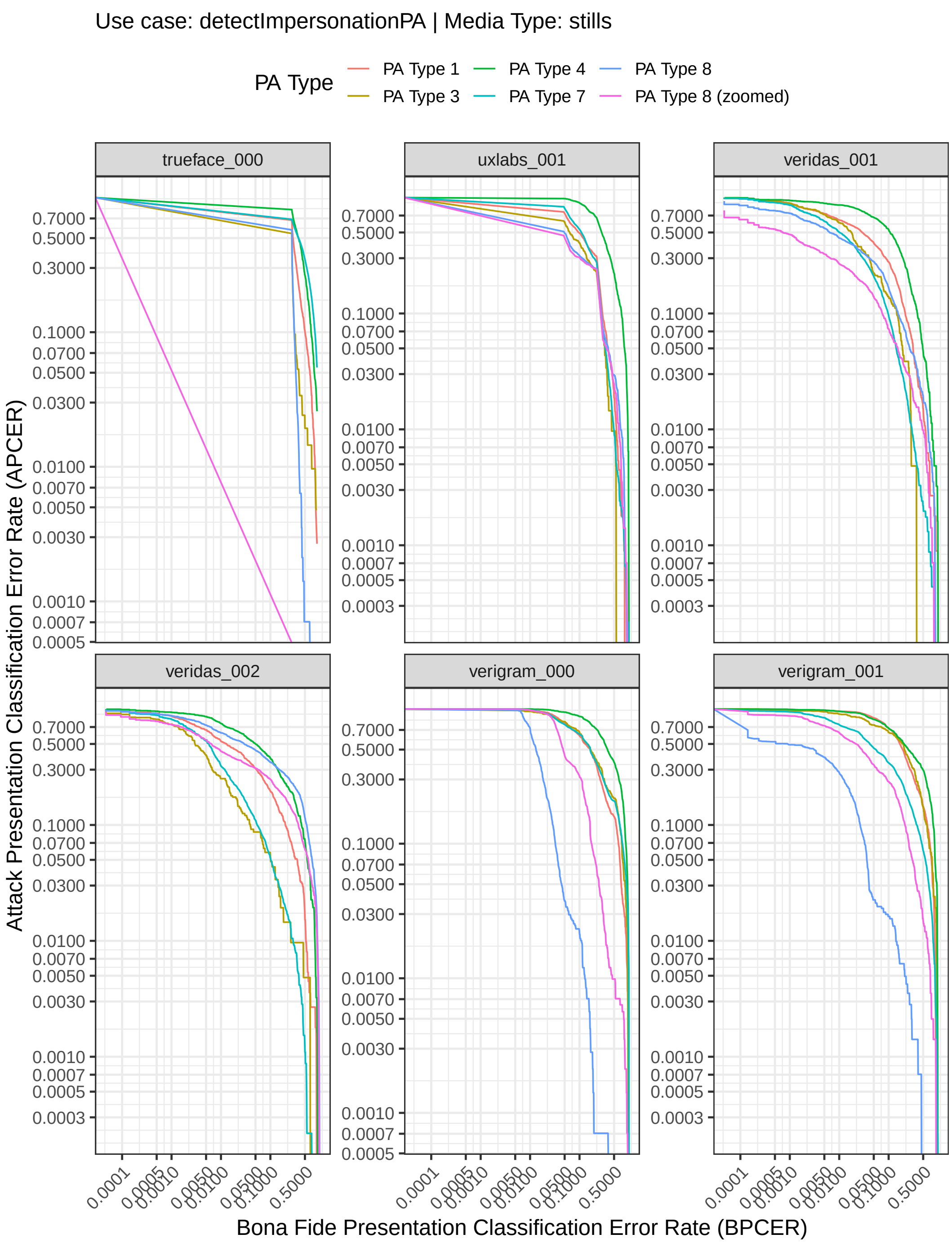


**Fig. 24.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

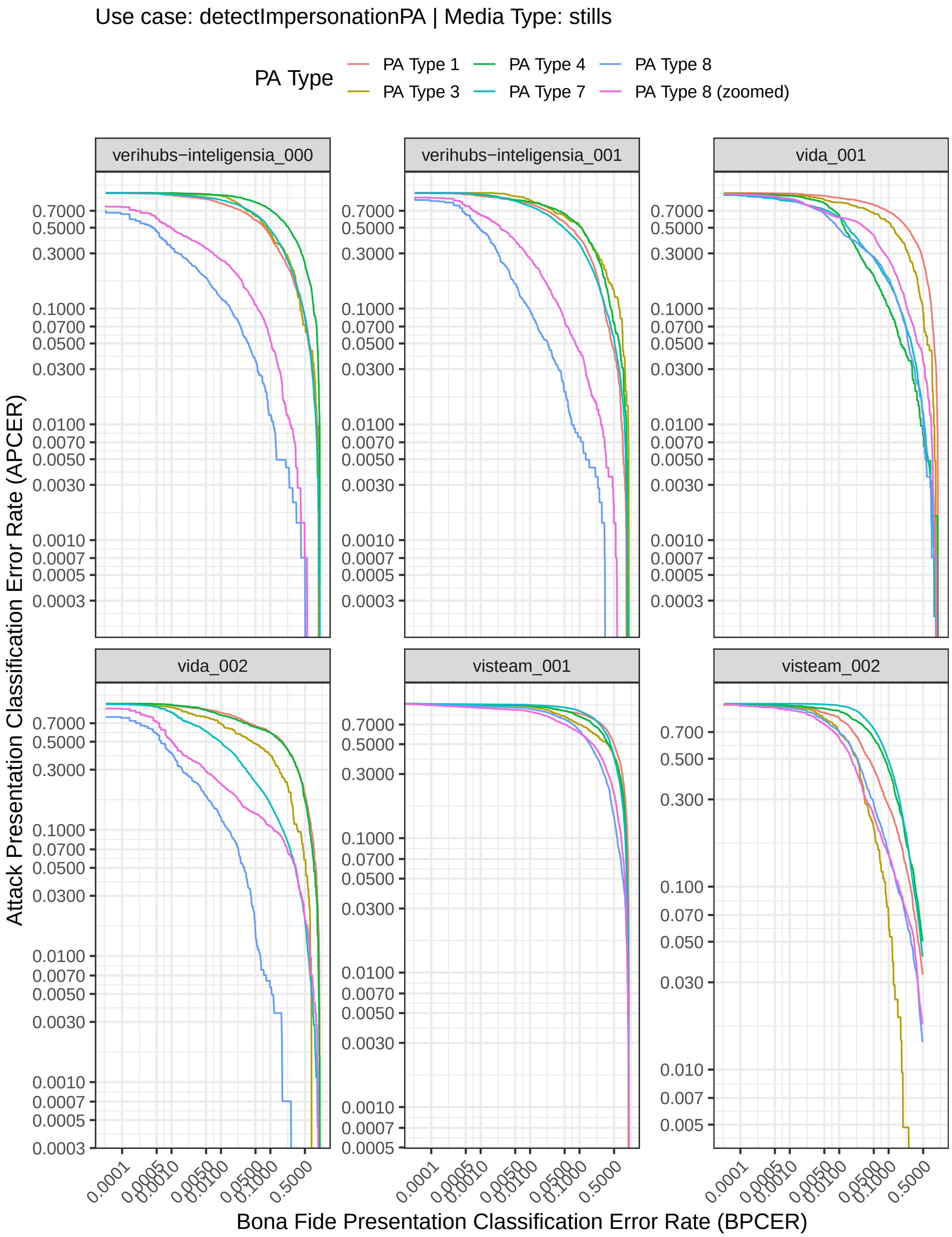


**Fig. 25.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA stills.

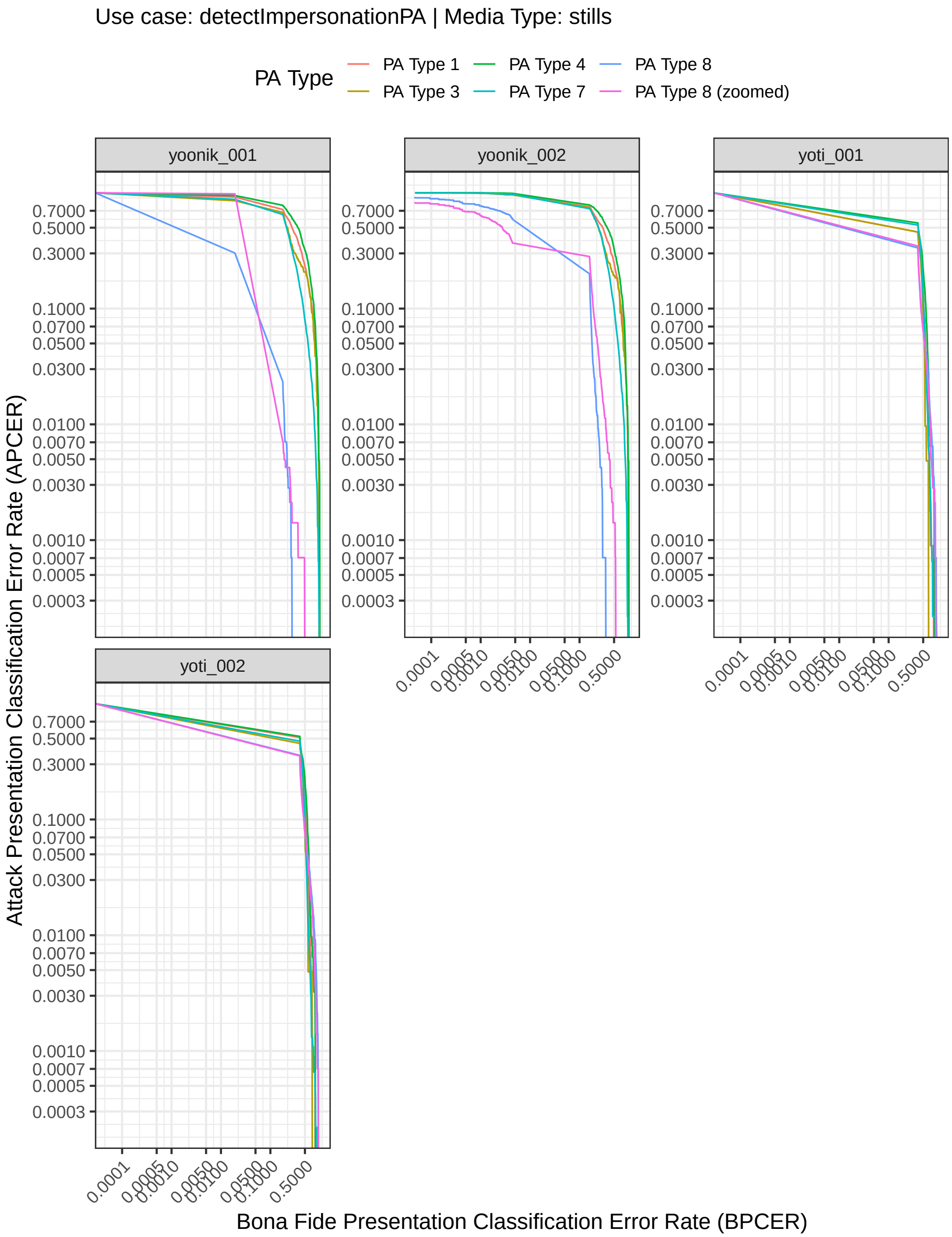


**Fig. 26.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

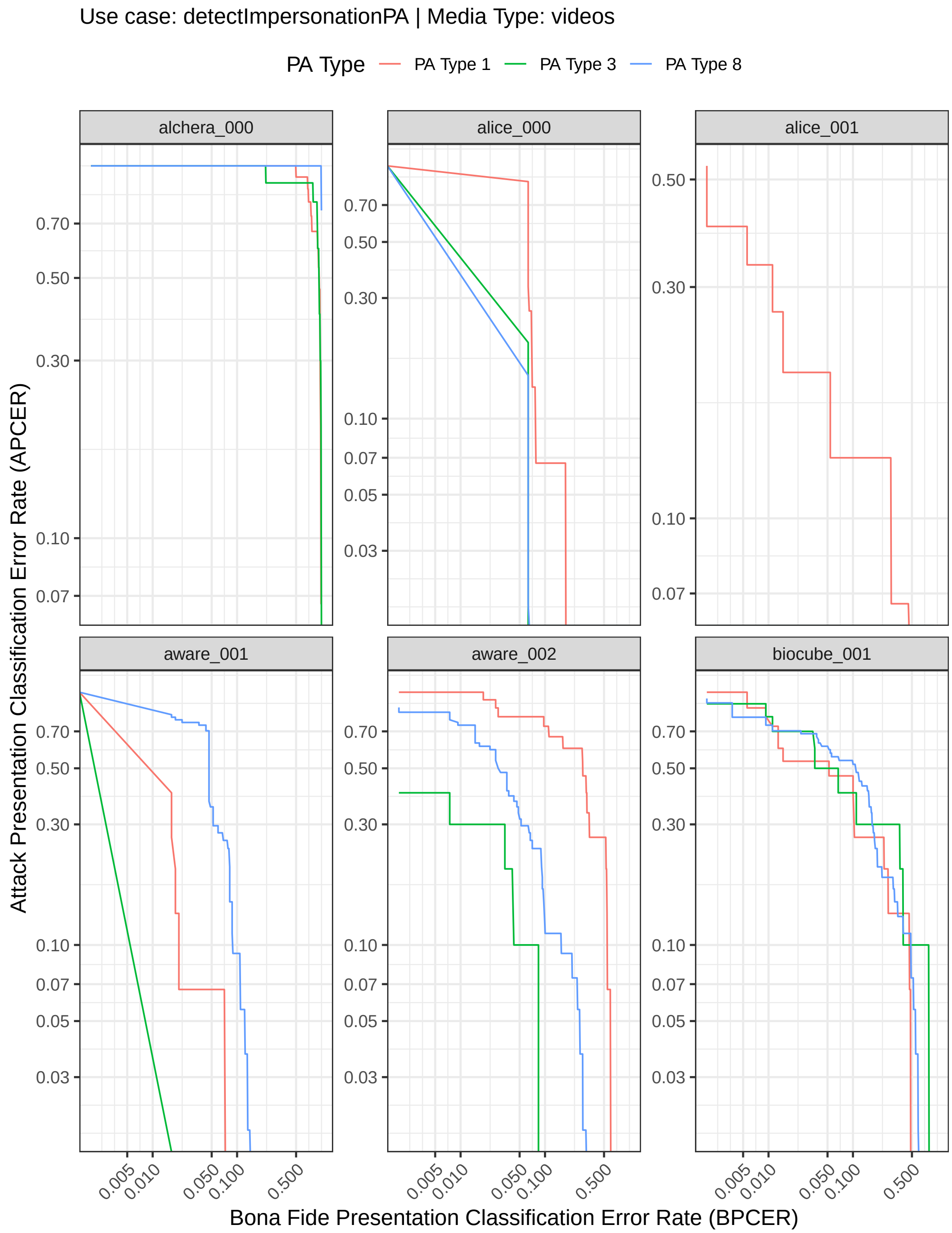


**Fig. 27.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

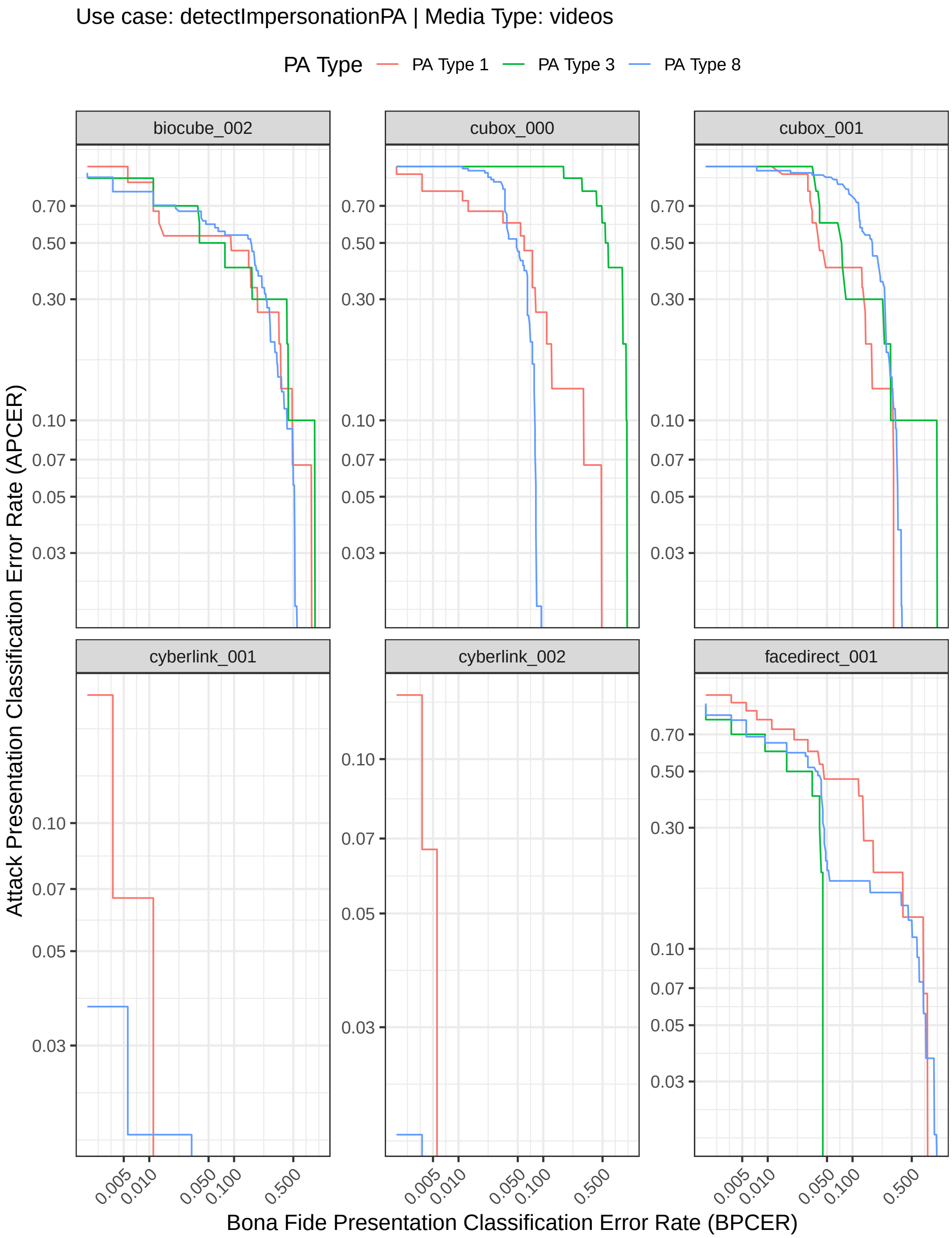


**Fig. 28.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

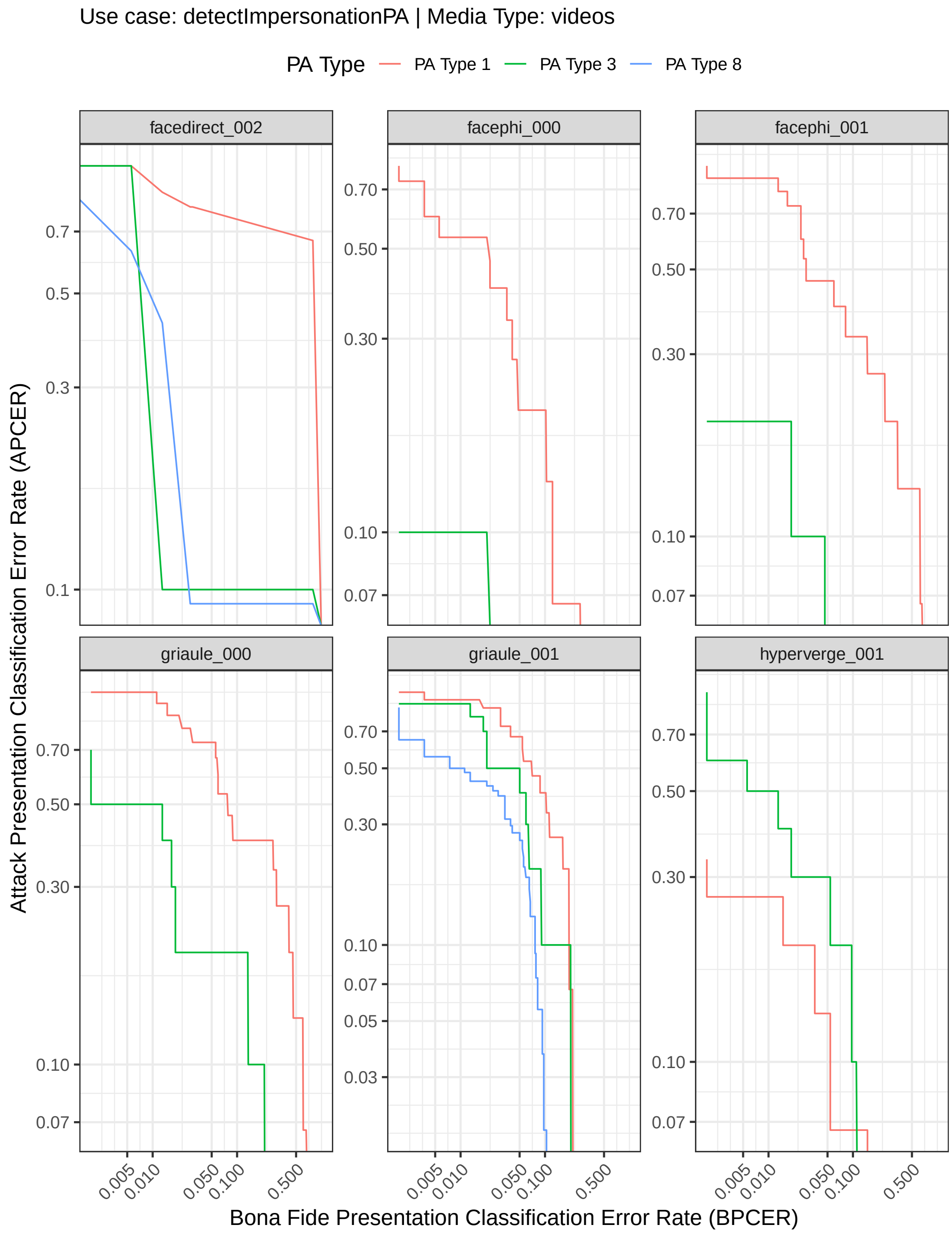


**Fig. 29.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

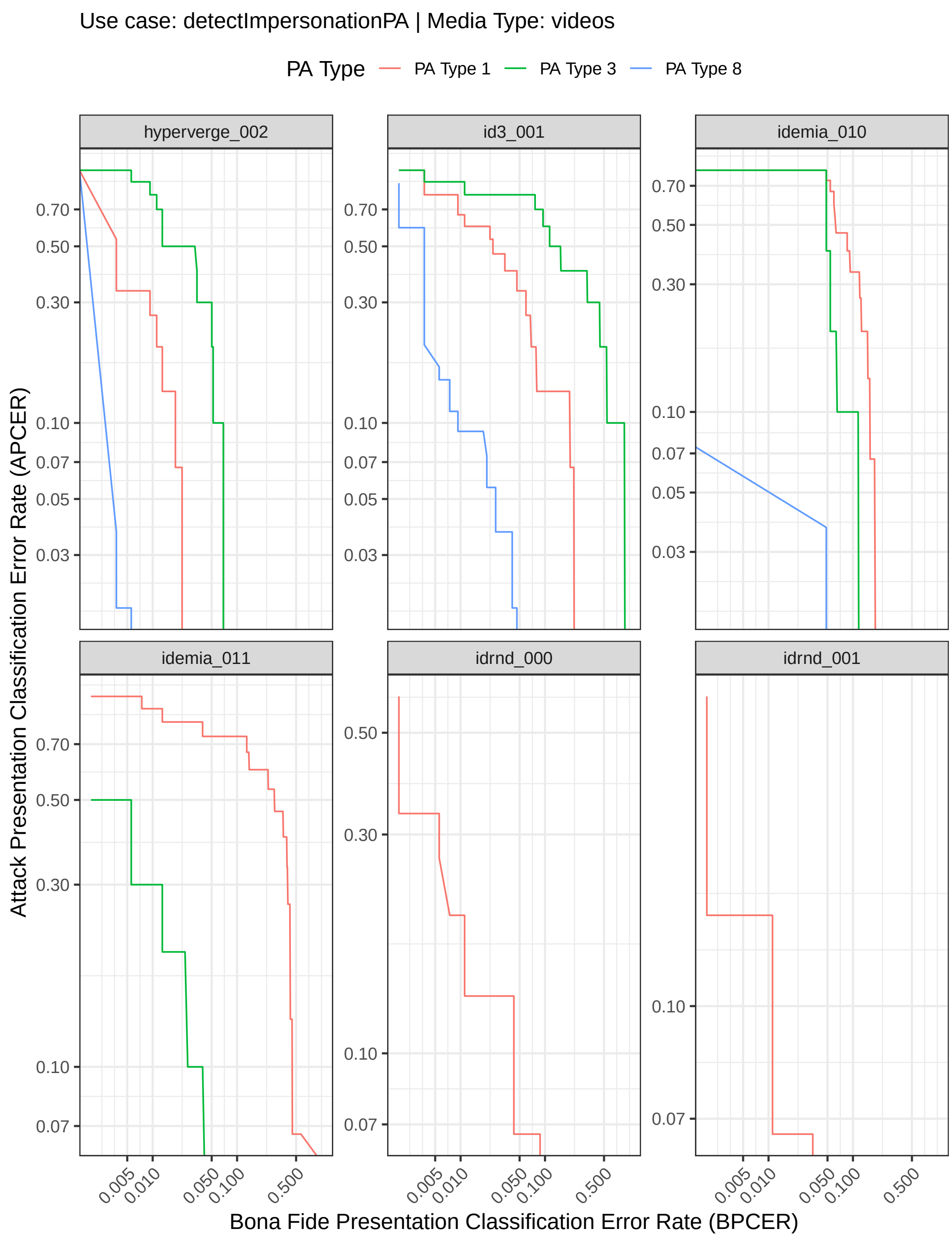


**Fig. 30.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

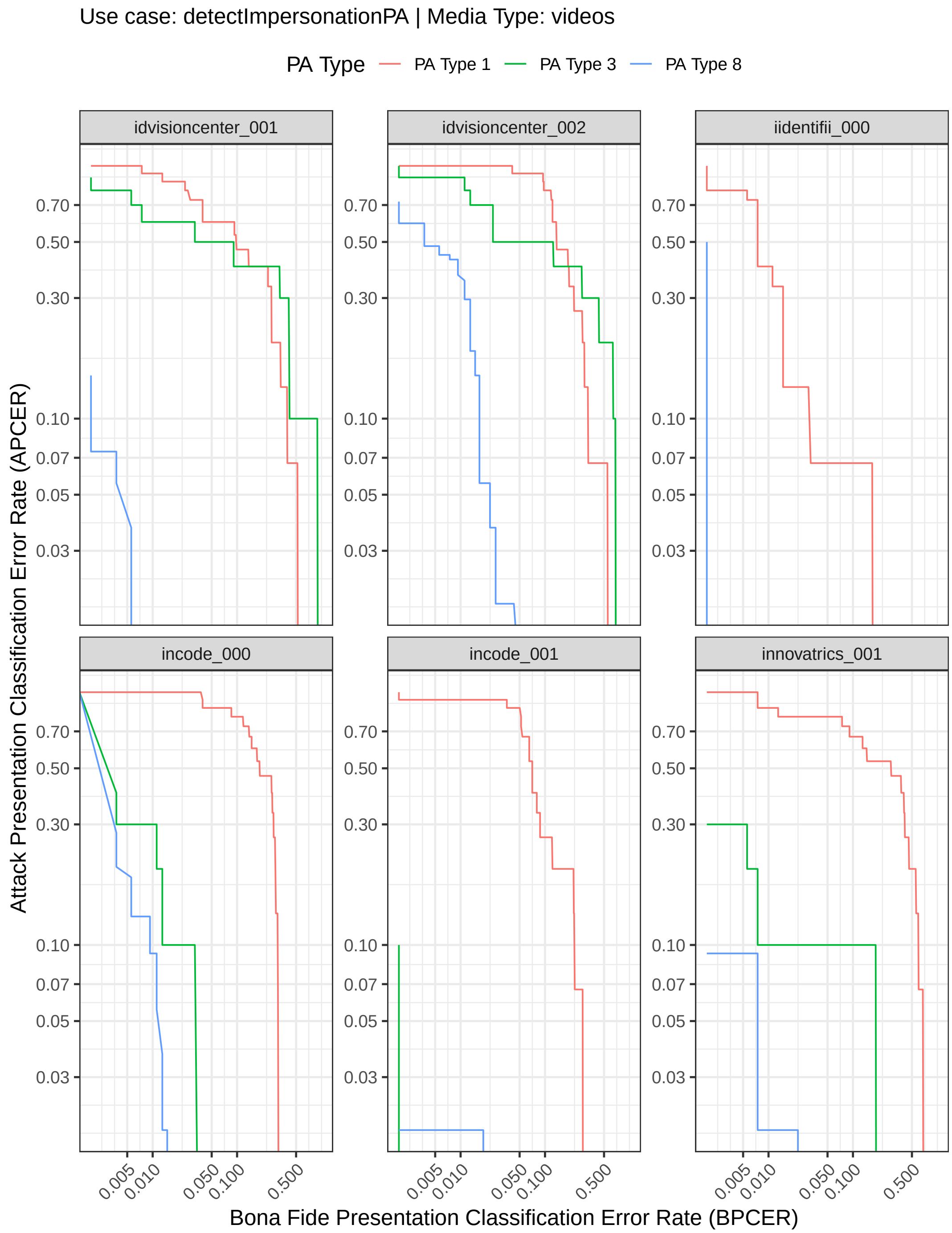


**Fig. 31.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

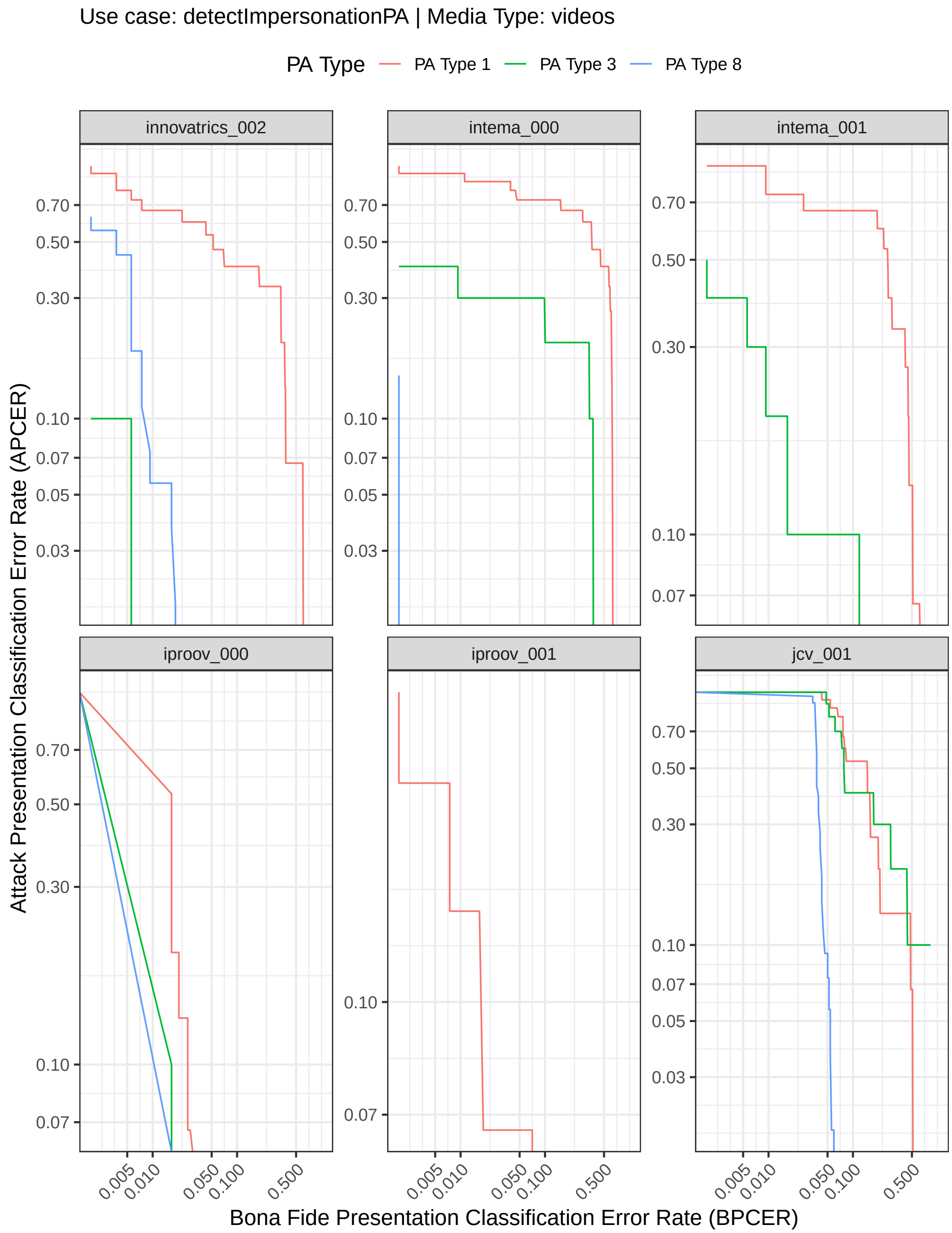


**Fig. 32.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

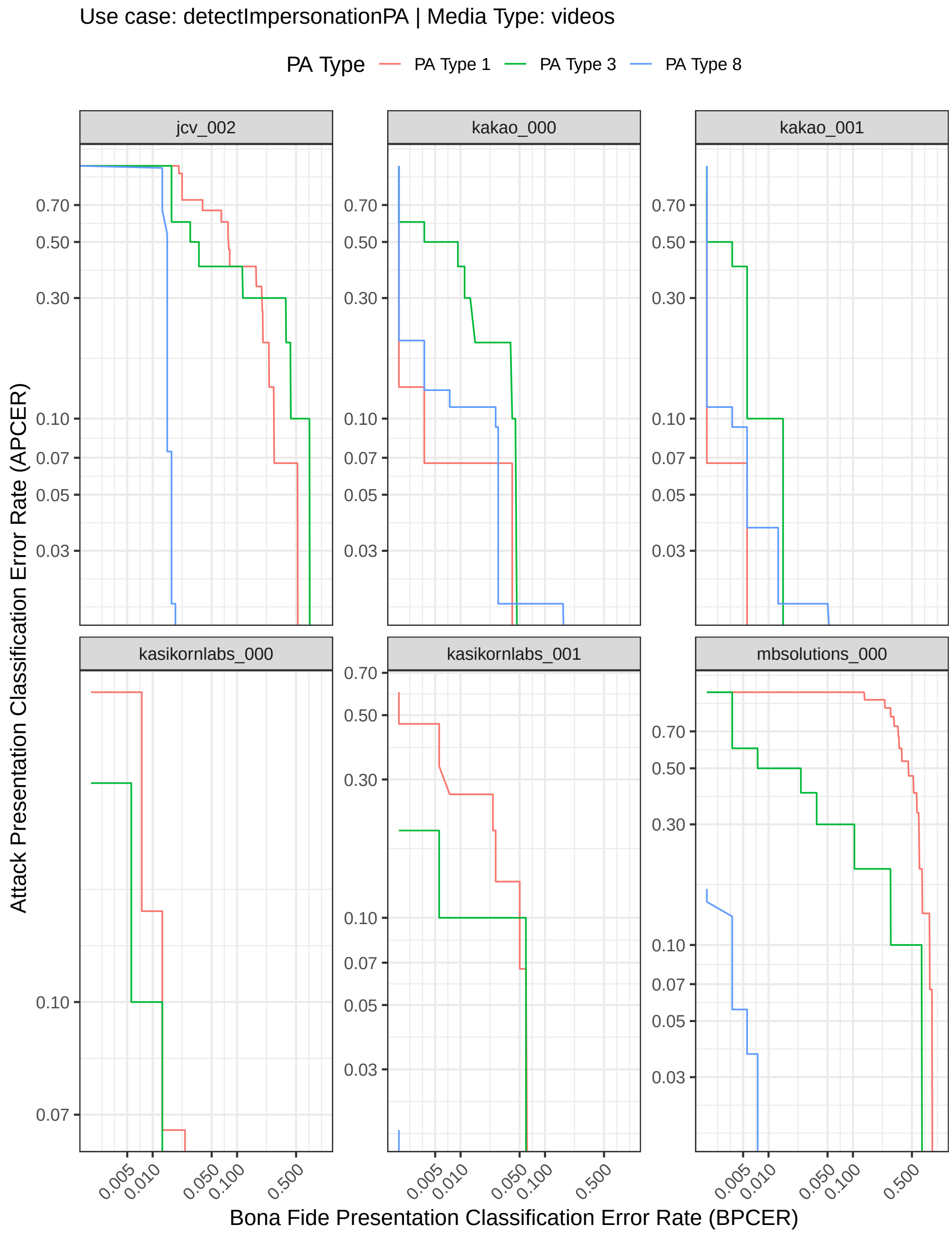


**Fig. 33.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

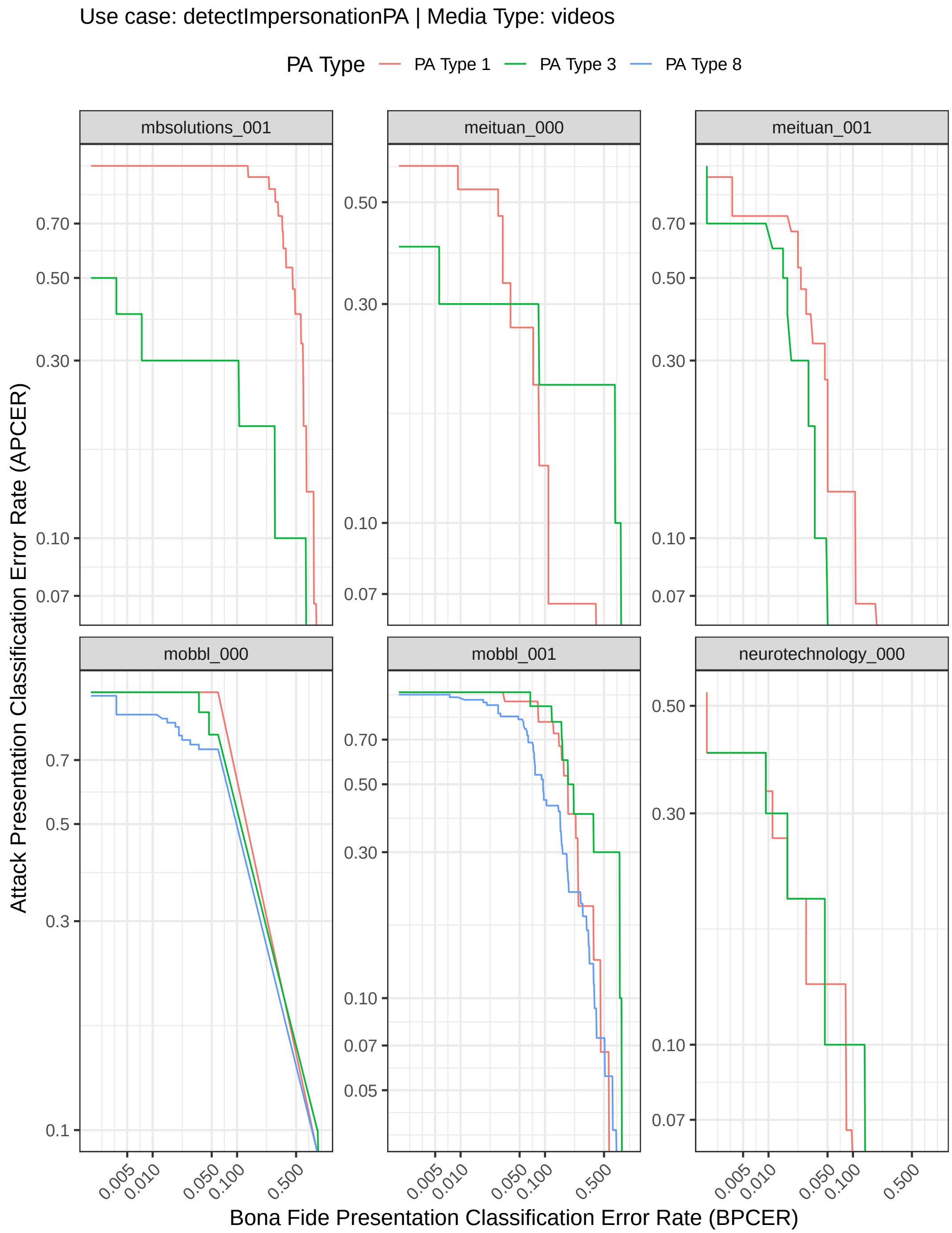


**Fig. 34.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

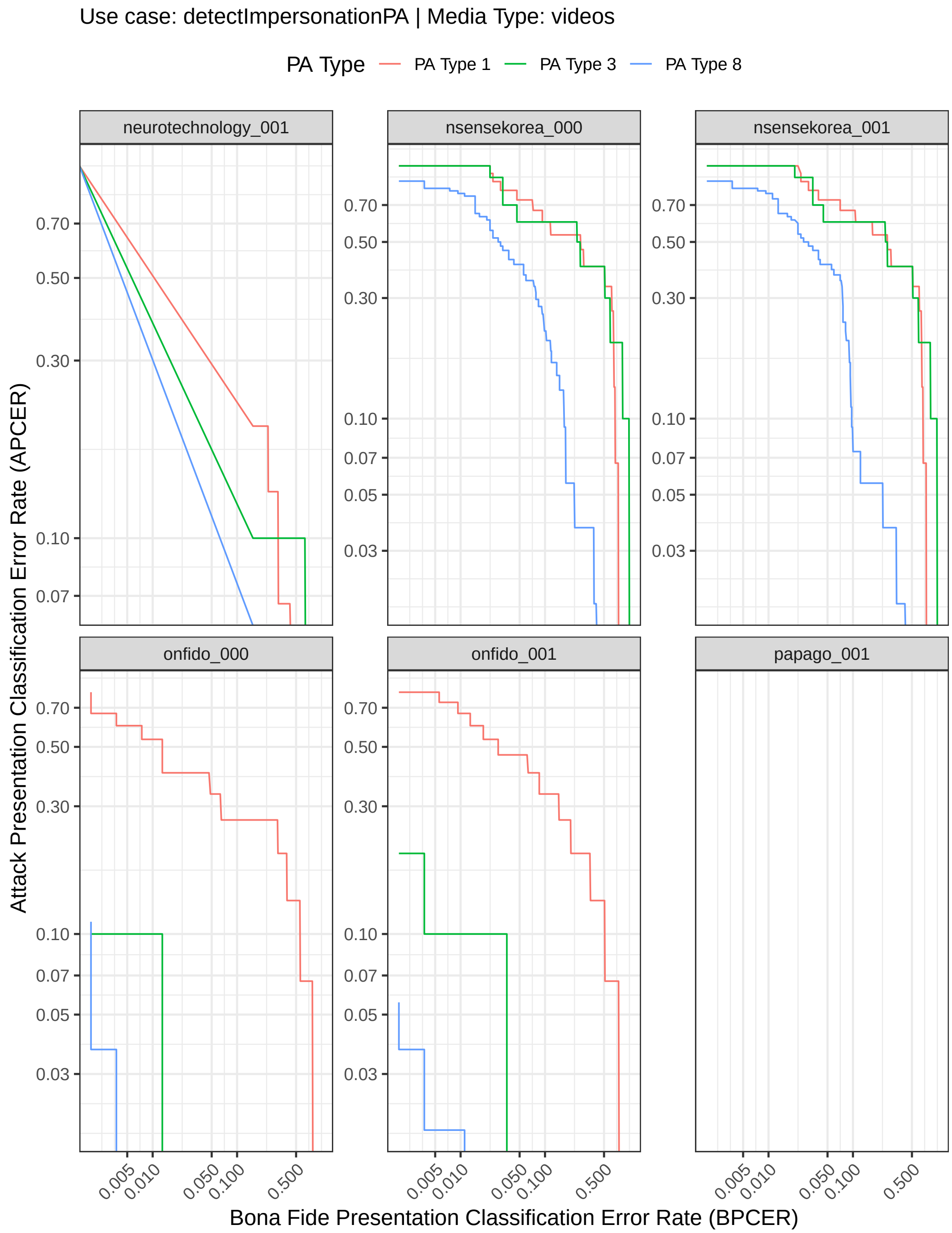


**Fig. 35.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

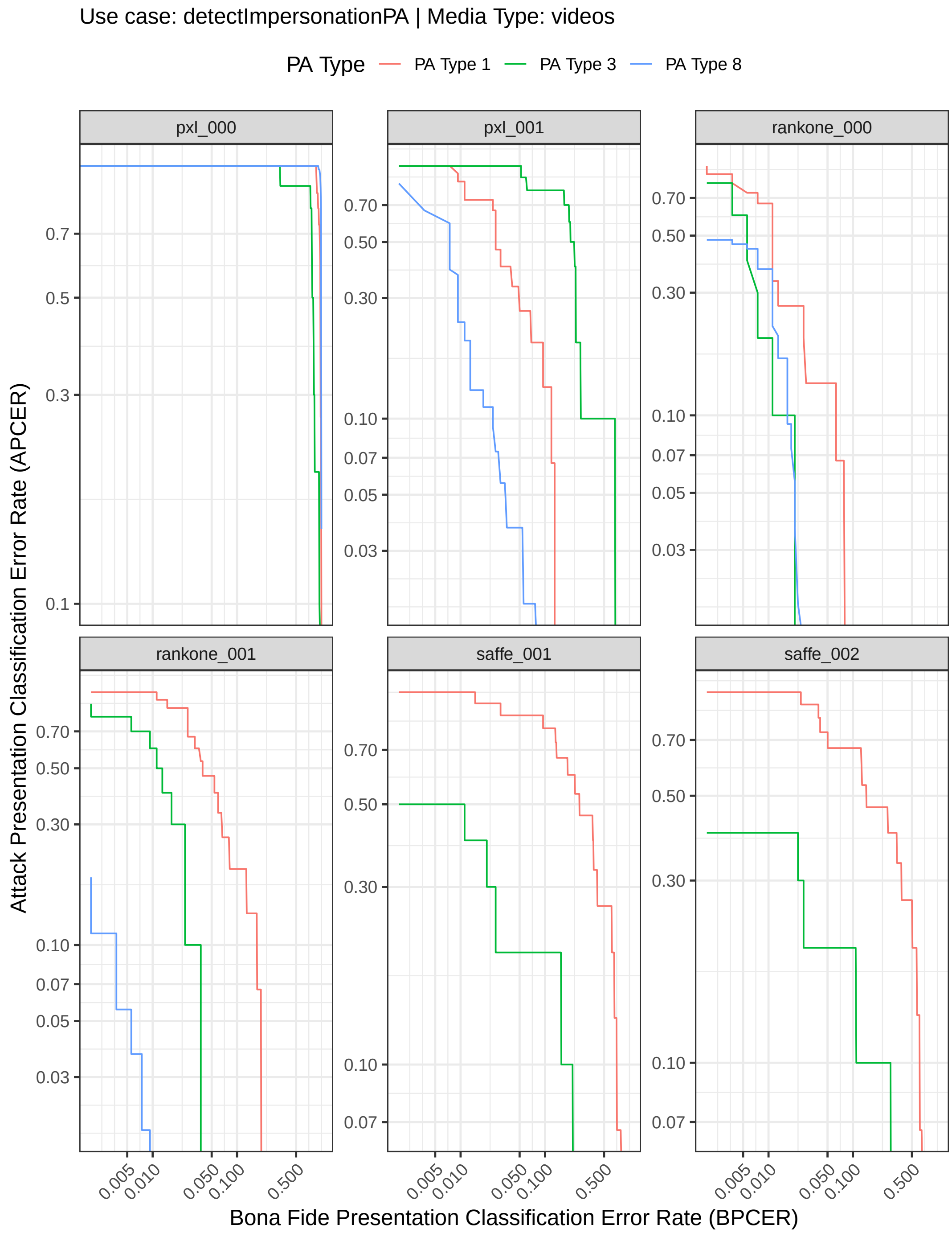


**Fig. 36.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

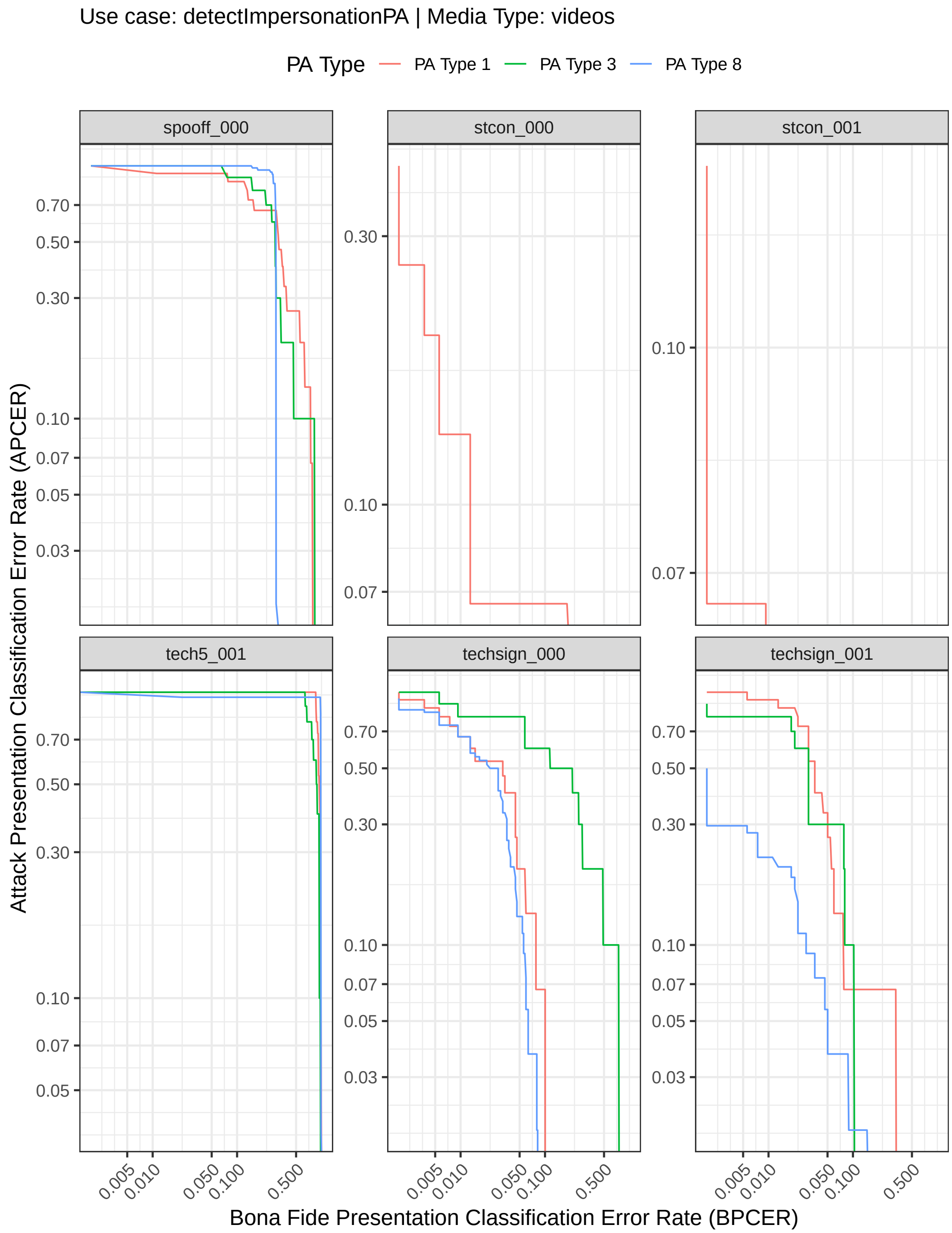


**Fig. 37.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

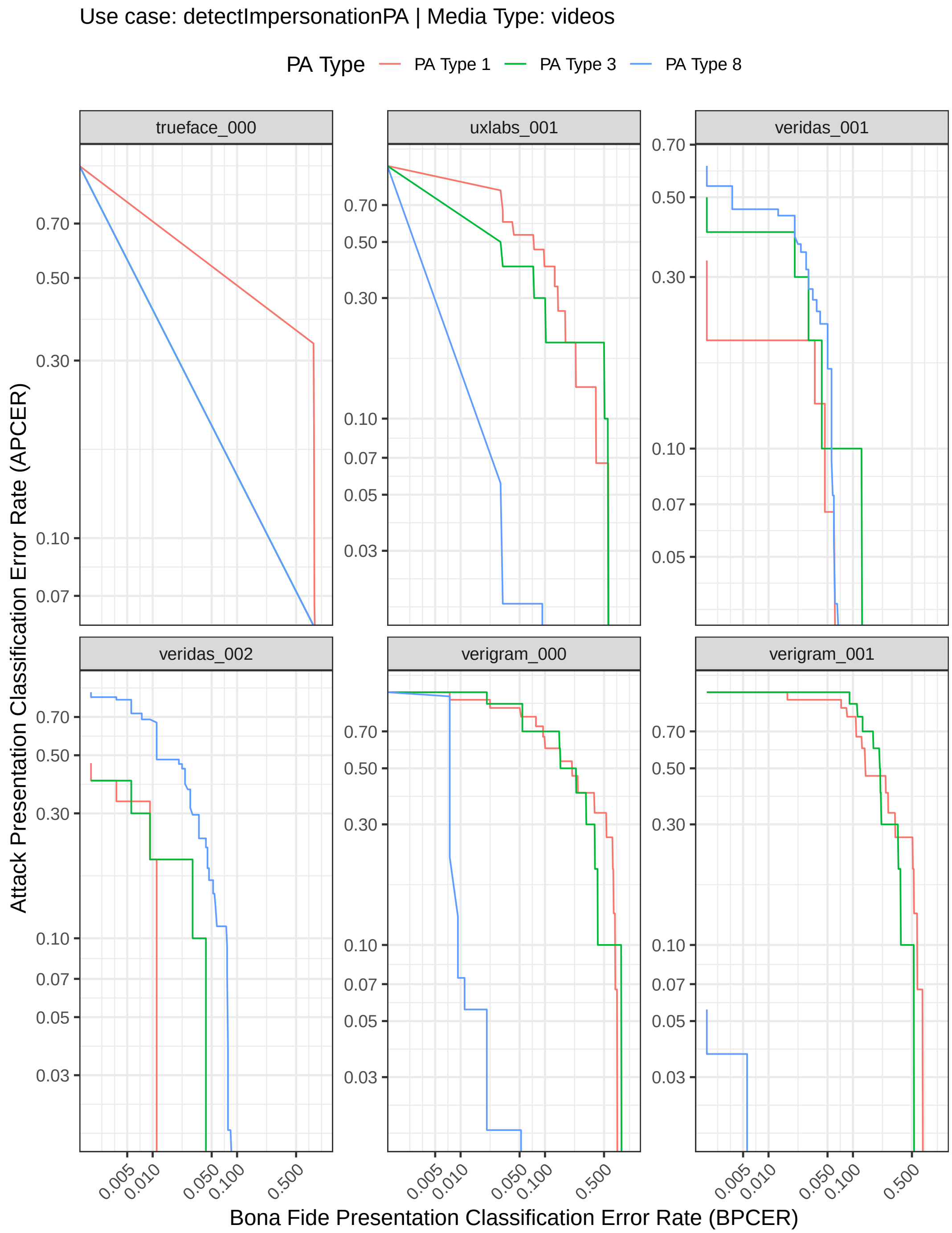


**Fig. 38.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.

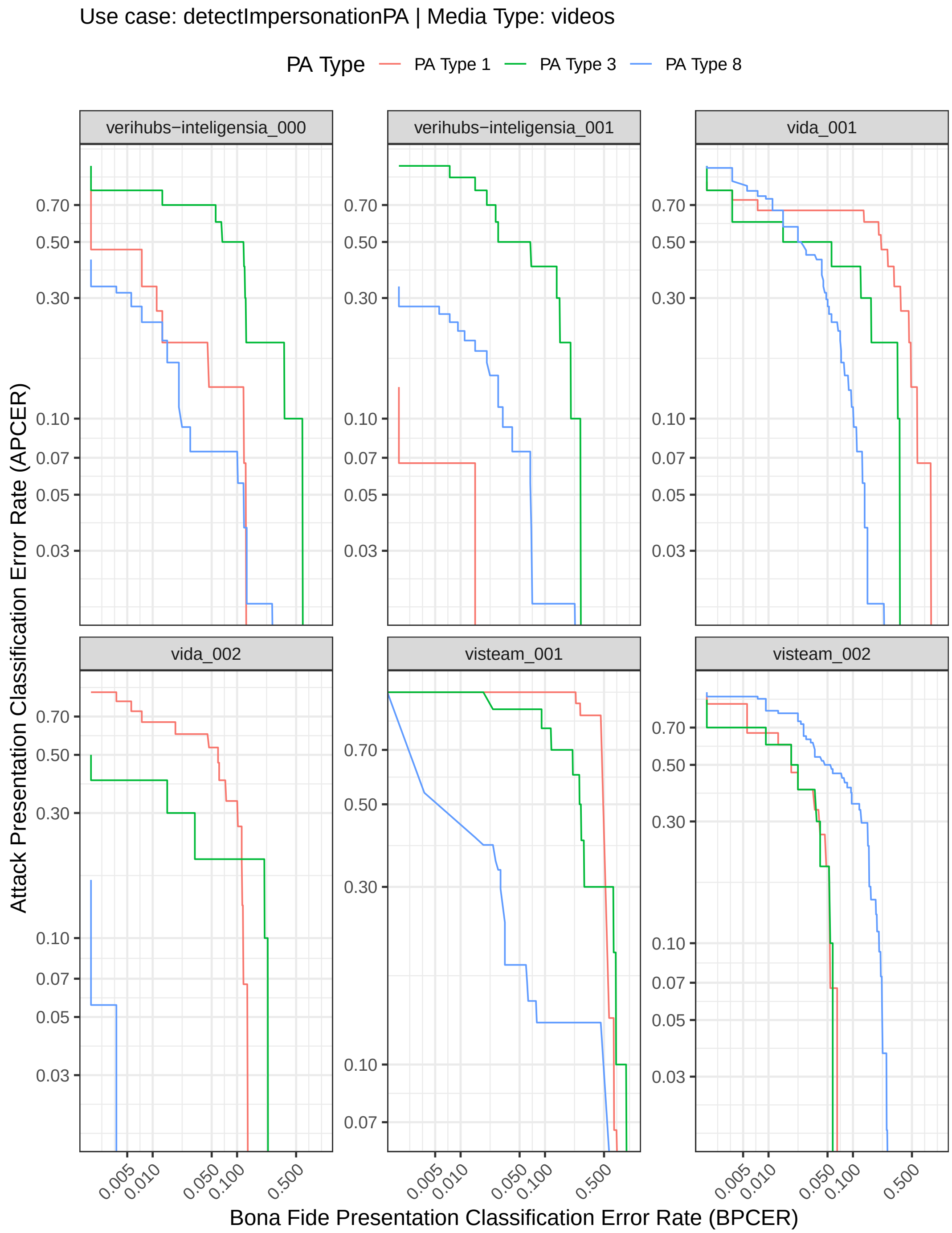
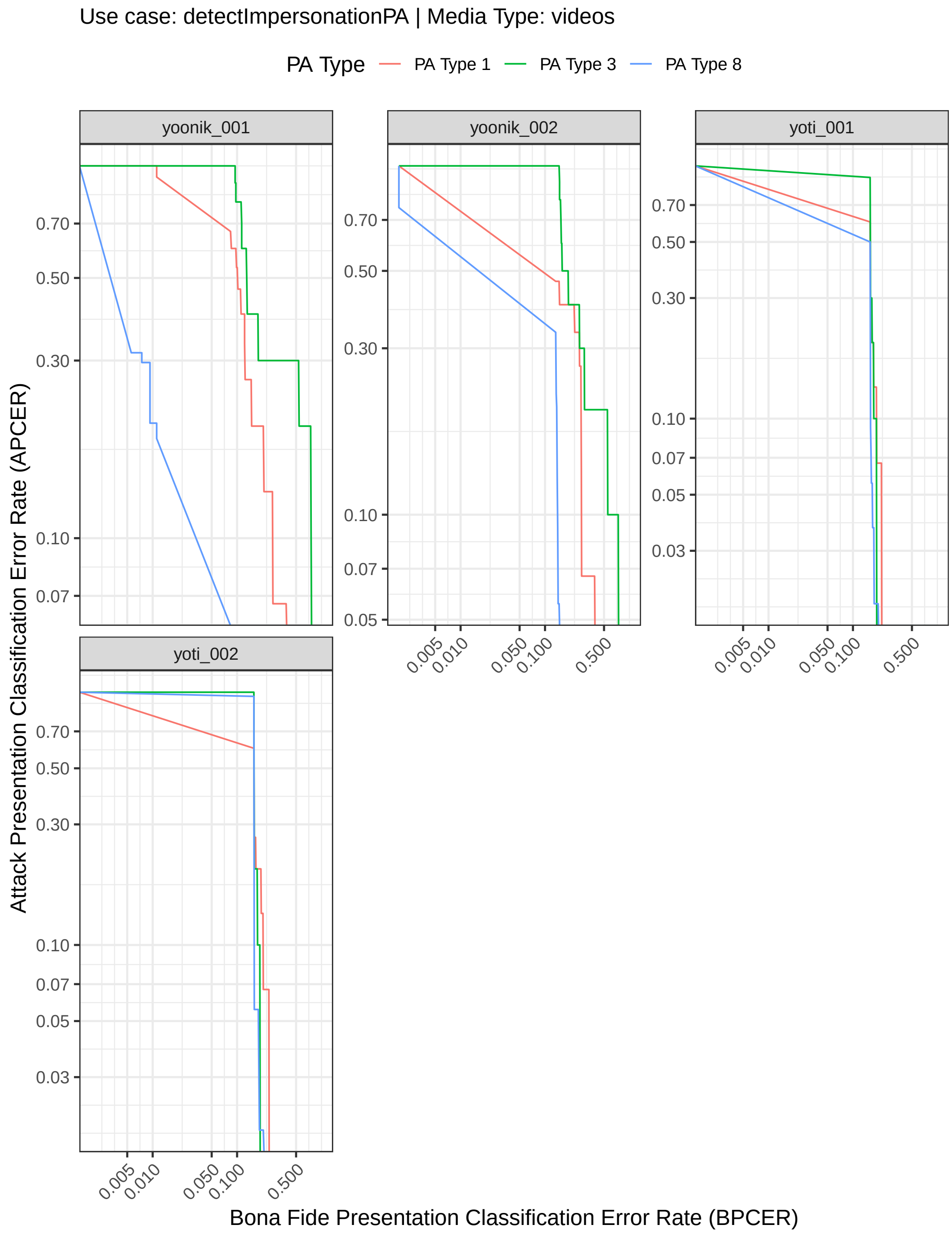


**Fig. 39.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of impersonation PA videos.



## Appendix A.3. Evasion

**Table 39.** PA Type 1 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.000 | 0.000 | 0.13 ± 0.01 | 1 | 0.151 | 1 |
| kakao-000 | 0.000 | 0.000 | 0.28 ± 0.02 | 2 | 0.635 | 9 |
| rankone-000 | 0.000 | 0.000 | 0.39 ± 0.02 | 3 | 0.665 | 10 |
| rankone-001 | 0.000 | 0.000 | 0.39 ± 0.02 | 3 | 0.665 | 10 |
| kasikornlabs-000 | 0.024 | 0.000 | 0.4 ± 0.02 | 5 | 0.495 | 4 |
| cyberlink-002 | 0.000 | 0.000 | 0.44 ± 0.02 | 6 | 0.254 | 2 |
| aware-002 | 0.000 | 0.000 | 0.51 ± 0.02 | 7 | 0.418 | 3 |
| neurotechnology-000 | 0.000 | 0.000 | 0.53 ± 0.02 | 8 | 1.000 | 24 |
| kasikornlabs-001 | 0.024 | 0.000 | 0.53 ± 0.02 | 9 | 0.542 | 7 |
| onfido-000 | 0.049 | 0.000 | 0.55 ± 0.02 | 10 | 0.934 | 15 |
| onfido-001 | 0.049 | 0.000 | 0.62 ± 0.02 | 11 | 0.696 | 12 |
| facedirect-002 | 0.000 | 0.000 | 0.73 ± 0.02 | 12 | 1.000 | 24 |
| trueface-000 | 0.000 | 0.000 | 0.75 ± 0.01 | 13 | 1.000 | 24 |
| griaule-001 | 0.000 | 0.000 | 0.79 ± 0.01 | 14 | 0.989 | 19 |
| griaule-000 | 0.000 | 0.000 | 0.86 ± 0.01 | 15 | 0.998 | 20 |
| facedirect-001 | 0.000 | 0.000 | 0.88 ± 0.01 | 16 | 0.978 | 16 |
| cyberlink-001 | 0.001 | 0.001 | 0.88 ± 0.01 | 17 | 0.696 | 12 |
| cubox-000 | 0.003 | 0.000 | 0.928 ± 0.009 | 18 | 0.978 | 16 |
| cubox-001 | 0.003 | 0.000 | 0.974 ± 0.006 | 19 | 1.000 | 21 |
| spooff-000 | 0.000 | 0.000 | 0.976 ± 0.005 | 20 | 1.000 | 24 |
| papago-001 | 0.000 | 0.000 | 0.989 ± 0.003 | 21 | 1.000 | 21 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.003 | 22 | 0.989 | 18 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0.0005 | 23 | 1.000 | 21 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.517 | 6 |
| aware-001 | 0.148 | 0.035 | 1 ± 0 | 24 | 0.507 | 5 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.863 | 14 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.600 | 8 |

**Table 40.** PA Type 2 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.000 | 0.000 | 0.12 ± 0.06 | 1 | 0.108 | 3 |
| onfido-000 | 0.000 | 0.000 | 0.17 ± 0.07 | 2 | 0.221 | 6 |
| kakao-000 | 0.000 | 0.000 | 0.18 ± 0.07 | 3 | 0.315 | 8 |
| aware-002 | 0.000 | 0.000 | 0.33 ± 0.09 | 4 | 0.173 | 5 |
| onfido-001 | 0.000 | 0.000 | 0.4 ± 0.1 | 5 | 0.463 | 12 |
| neurotechnology-000 | 0.000 | 0.000 | 0.4 ± 0.1 | 6 | 0.297 | 7 |
| cyberlink-002 | 0.000 | 0.000 | 0.4 ± 0.1 | 7 | 0.077 | 2 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.5 ± 0.1 | 8 | 0.437 | 11 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.6 ± 0.1 | 9 | 0.386 | 10 |
| facedirect-002 | 0.000 | 0.000 | 0.64 ± 0.09 | 10 | 1.000 | 25 |
| rankone-000 | 0.000 | 0.000 | 0.72 ± 0.09 | 11 | 0.643 | 13 |
| rankone-001 | 0.000 | 0.000 | 0.72 ± 0.09 | 11 | 0.643 | 13 |
| facedirect-001 | 0.000 | 0.000 | 0.83 ± 0.07 | 13 | 0.903 | 17 |
| trueface-000 | 0.000 | 0.000 | 0.96 ± 0.03 | 14 | 1.000 | 25 |
| griaule-000 | 0.000 | 0.000 | 0.98 ± 0.02 | 15 | 0.978 | 20 |
| cubox-000 | 0.000 | 0.000 | 0.99 ± 0.01 | 16 | 0.989 | 21 |
| cyberlink-001 | 0.000 | 0.001 | 0.99 ± 0.01 | 16 | 0.361 | 9 |
| griaule-001 | 0.000 | 0.000 | 0.99 ± 0.01 | 16 | 0.924 | 18 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.035 | 1 |
| aware-001 | 0.105 | 0.035 | 1 ± 0 | 19 | 0.171 | 4 |
| cubox-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.967 | 19 |
| jcv-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 22 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.643 | 13 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 23 |
| spooff-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 25 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.711 | 16 |

**Table 41.** PA Type 3 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| onfido-000 | 0.000 | 0.000 | 0.05 ± 0.03 | 1 | 0.036 | 2 |
| onfido-001 | 0.000 | 0.000 | 0.09 ± 0.04 | 2 | 0.051 | 4 |
| aware-002 | 0.000 | 0.000 | 0.1 ± 0.04 | 3 | 0.057 | 6 |
| facedirect-002 | 0.000 | 0.000 | 0.16 ± 0.05 | 4 | 0.989 | 23 |
| neurotechnology-000 | 0.000 | 0.000 | 0.26 ± 0.06 | 5 | 0.197 | 7 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.26 ± 0.06 | 6 | 0.251 | 8 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.29 ± 0.06 | 7 | 0.329 | 10 |
| kakao-001 | 0.000 | 0.000 | 0.56 ± 0.07 | 8 | 0.452 | 13 |
| cyberlink-002 | 0.000 | 0.000 | 0.6 ± 0.07 | 9 | 0.041 | 3 |
| kakao-000 | 0.000 | 0.000 | 0.68 ± 0.06 | 10 | 0.834 | 17 |
| rankone-000 | 0.000 | 0.000 | 0.75 ± 0.06 | 11 | 0.753 | 15 |
| rankone-001 | 0.000 | 0.000 | 0.75 ± 0.06 | 11 | 0.753 | 15 |
| facedirect-001 | 0.000 | 0.000 | 0.83 ± 0.05 | 13 | 0.390 | 11 |
| cubox-000 | 0.000 | 0.000 | 0.92 ± 0.04 | 14 | 0.967 | 19 |
| cubox-001 | 0.000 | 0.000 | 0.95 ± 0.03 | 15 | 0.934 | 18 |
| trueface-000 | 0.000 | 0.000 | 0.98 ± 0.02 | 16 | 1.000 | 26 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.02 | 17 | 0.989 | 21 |
| griaule-001 | 0.000 | 0.000 | 0.995 ± 0.007 | 18 | 1.000 | 24 |
| papago-001 | 0.000 | 0.000 | 0.995 ± 0.007 | 18 | 0.989 | 22 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 20 | 1.000 | 24 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 20 | 0.014 | 1 |
| aware-001 | 0.072 | 0.035 | 1 ± 0 | 20 | 0.052 | 5 |
| cyberlink-001 | 0.000 | 0.001 | 1 ± 0 | 20 | 0.574 | 14 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 20 | 0.978 | 20 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 20 | 0.297 | 9 |
| spooff-000 | 0.000 | 0.000 | 1 ± 0 | 20 | 1.000 | 26 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 20 | 0.447 | 12 |

**Table 42.** PA Type 4 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kasikornlabs-000 | 0.000 | 0.000 | 0.62 ± 0.04 | 1 | 0.452 | 4 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.62 ± 0.04 | 2 | 0.555 | 5 |
| cyberlink-002 | 0.000 | 0.000 | 0.63 ± 0.04 | 3 | 0.446 | 3 |
| onfido-001 | 0.000 | 0.000 | 0.74 ± 0.03 | 4 | 0.621 | 6 |
| aware-002 | 0.000 | 0.000 | 0.76 ± 0.03 | 5 | 0.348 | 2 |
| kakao-001 | 0.000 | 0.000 | 0.82 ± 0.03 | 6 | 0.815 | 9 |
| onfido-000 | 0.000 | 0.000 | 0.82 ± 0.03 | 6 | 0.788 | 7 |
| kakao-000 | 0.000 | 0.000 | 0.89 ± 0.03 | 8 | 0.912 | 11 |
| facedirect-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 9 | 0.989 | 19 |
| cubox-001 | 0.000 | 0.000 | 0.9 ± 0.02 | 10 | 0.967 | 16 |
| rankone-000 | 0.000 | 0.000 | 0.91 ± 0.02 | 11 | 0.913 | 12 |
| rankone-001 | 0.000 | 0.000 | 0.91 ± 0.02 | 11 | 0.913 | 12 |
| neurotechnology-000 | 0.000 | 0.000 | 0.91 ± 0.02 | 13 | 1.000 | 25 |
| cubox-000 | 0.000 | 0.000 | 0.95 ± 0.02 | 14 | 0.967 | 16 |
| cyberlink-001 | 0.000 | 0.001 | 0.98 ± 0.01 | 15 | 0.945 | 14 |
| facedirect-002 | 0.000 | 0.000 | 0.98 ± 0.01 | 16 | 0.989 | 21 |
| jcv-001 | 0.000 | 0.000 | 0.987 ± 0.009 | 17 | 0.989 | 18 |
| papago-001 | 0.000 | 0.000 | 0.992 ± 0.007 | 18 | 0.989 | 19 |
| alchera-000 | 0.000 | 0.000 | 0.997 ± 0.004 | 19 | 1.000 | 23 |
| spooff-000 | 0.000 | 0.000 | 0.998 ± 0.002 | 20 | 1.000 | 25 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 21 | 0.813 | 8 |
| aware-001 | 0.139 | 0.035 | 1 ± 0 | 21 | 0.191 | 1 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 21 | 0.998 | 22 |
| griaule-001 | 0.000 | 0.000 | 1 ± 0 | 21 | 1.000 | 23 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 21 | 0.883 | 10 |
| trueface-000 | 0.000 | 0.000 | 1 ± 0 | 21 | 1.000 | 25 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 21 | 0.964 | 15 |

**Table 43.** PA Type 5 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.001 | 1 |
| kakao-000 | 0.000 | 0.000 | 0.02 ± 0.01 | 2 | 0.034 | 2 |
| cyberlink-002 | 0.000 | 0.000 | 0.34 ± 0.06 | 3 | 0.560 | 7 |
| facedirect-002 | 0.000 | 0.000 | 0.44 ± 0.06 | 4 | 1.000 | 25 |
| aware-002 | 0.000 | 0.000 | 0.65 ± 0.06 | 5 | 0.390 | 4 |
| griaule-000 | 0.000 | 0.000 | 0.68 ± 0.06 | 6 | 0.966 | 18 |
| rankone-000 | 0.000 | 0.000 | 0.73 ± 0.05 | 7 | 0.665 | 8 |
| rankone-001 | 0.000 | 0.000 | 0.73 ± 0.05 | 7 | 0.665 | 8 |
| onfido-001 | 0.000 | 0.000 | 0.79 ± 0.05 | 9 | 0.788 | 11 |
| onfido-000 | 0.000 | 0.000 | 0.82 ± 0.04 | 10 | 0.844 | 12 |
| griaule-001 | 0.000 | 0.000 | 0.85 ± 0.04 | 11 | 0.989 | 19 |
| trueface-000 | 0.000 | 0.000 | 0.9 ± 0.04 | 12 | 1.000 | 25 |
| neurotechnology-000 | 0.000 | 0.000 | 0.92 ± 0.03 | 13 | 1.000 | 25 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.96 ± 0.02 | 14 | 0.989 | 19 |
| cyberlink-001 | 0.000 | 0.001 | 0.97 ± 0.02 | 15 | 0.873 | 14 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.97 ± 0.02 | 16 | 0.989 | 19 |
| cubox-000 | 0.000 | 0.000 | 0.98 ± 0.01 | 17 | 0.934 | 17 |
| cubox-001 | 0.000 | 0.000 | 0.99 ± 0.01 | 18 | 0.924 | 16 |
| facedirect-001 | 0.000 | 0.000 | 0.99 ± 0.01 | 18 | 1.000 | 23 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.01 | 20 | 1.000 | 22 |
| spooff-000 | 0.000 | 0.000 | 0.99 ± 0.01 | 20 | 0.497 | 6 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 22 | 1.000 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.851 | 13 |
| aware-001 | 0.004 | 0.035 | 1 ± 0 | 22 | 0.495 | 5 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.913 | 15 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.696 | 10 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.207 | 3 |

**Table 44.** PA Type 6 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| rankone-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 1 |
| rankone-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.000 | 1 |
| trueface-000 | 0.000 | 0.000 | 0.002 ± 0.002 | 3 | 0.003 | 3 |
| kakao-000 | 0.000 | 0.000 | 0.008 ± 0.005 | 4 | 0.004 | 4 |
| cyberlink-002 | 0.000 | 0.000 | 0.012 ± 0.006 | 5 | 0.011 | 5 |
| kakao-001 | 0.000 | 0.000 | 0.014 ± 0.007 | 6 | 0.012 | 6 |
| neurotechnology-000 | 0.000 | 0.000 | 0.21 ± 0.02 | 7 | 0.226 | 13 |
| griaule-001 | 0.000 | 0.000 | 0.34 ± 0.03 | 8 | 0.337 | 14 |
| griaule-000 | 0.000 | 0.000 | 0.49 ± 0.03 | 9 | 0.447 | 15 |
| aware-002 | 0.000 | 0.000 | 0.51 ± 0.03 | 10 | 0.053 | 8 |
| kasikornlabs-000 | 0.028 | 0.000 | 0.69 ± 0.03 | 11 | 0.567 | 16 |
| cyberlink-001 | 0.000 | 0.001 | 0.73 ± 0.02 | 12 | 0.119 | 9 |
| facedirect-002 | 0.000 | 0.000 | 0.75 ± 0.02 | 13 | 1.000 | 26 |
| kasikornlabs-001 | 0.028 | 0.000 | 0.8 ± 0.02 | 14 | 0.657 | 18 |
| onfido-001 | 0.046 | 0.000 | 0.81 ± 0.02 | 15 | 0.587 | 17 |
| facedirect-001 | 0.000 | 0.000 | 0.86 ± 0.02 | 16 | 0.967 | 20 |
| onfido-000 | 0.046 | 0.000 | 0.9 ± 0.02 | 17 | 1.000 | 22 |
| cubox-000 | 0.001 | 0.000 | 0.92 ± 0.02 | 18 | 0.934 | 19 |
| spooff-000 | 0.000 | 0.000 | 0.94 ± 0.01 | 19 | 1.000 | 26 |
| cubox-001 | 0.001 | 0.000 | 0.988 ± 0.006 | 20 | 1.000 | 22 |
| papago-001 | 0.000 | 0.000 | 0.989 ± 0.006 | 21 | 1.000 | 22 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.005 | 22 | 1.000 | 21 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 23 | 1.000 | 22 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.138 | 11 |
| aware-001 | 0.178 | 0.035 | 1 ± 0 | 23 | 0.038 | 7 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.224 | 12 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.133 | 10 |

**Table 45.** PA Type 7 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.000 | 0.000 | 0.14 ± 0.01 | 1 | 0.202 | 2 |
| kakao-000 | 0.000 | 0.000 | 0.15 ± 0.01 | 2 | 0.574 | 8 |
| onfido-001 | 0.001 | 0.000 | 0.34 ± 0.01 | 3 | 0.284 | 3 |
| onfido-000 | 0.001 | 0.000 | 0.43 ± 0.01 | 4 | 0.779 | 14 |
| rankone-000 | 0.000 | 0.000 | 0.52 ± 0.01 | 5 | 0.607 | 9 |
| rankone-001 | 0.000 | 0.000 | 0.52 ± 0.01 | 5 | 0.607 | 9 |
| cyberlink-002 | 0.000 | 0.000 | 0.52 ± 0.01 | 7 | 0.035 | 1 |
| neurotechnology-000 | 0.000 | 0.000 | 0.65 ± 0.01 | 8 | 0.525 | 7 |
| aware-002 | 0.000 | 0.000 | 0.8 ± 0.01 | 9 | 0.473 | 5 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.84 ± 0.01 | 10 | 0.728 | 12 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.86 ± 0.01 | 11 | 0.745 | 13 |
| facedirect-002 | 0.000 | 0.000 | 0.86 ± 0.01 | 12 | 1.000 | 25 |
| facedirect-001 | 0.000 | 0.000 | 0.86 ± 0.01 | 13 | 0.978 | 19 |
| trueface-000 | 0.000 | 0.000 | 0.922 ± 0.008 | 14 | 1.000 | 25 |
| cubox-001 | 0.000 | 0.000 | 0.949 ± 0.006 | 15 | 0.945 | 17 |
| griaule-001 | 0.000 | 0.000 | 0.957 ± 0.006 | 16 | 0.967 | 18 |
| griaule-000 | 0.000 | 0.000 | 0.96 ± 0.006 | 17 | 0.989 | 20 |
| cyberlink-001 | 0.001 | 0.001 | 0.975 ± 0.004 | 18 | 0.893 | 16 |
| cubox-000 | 0.000 | 0.000 | 0.98 ± 0.004 | 19 | 0.989 | 20 |
| papago-001 | 0.000 | 0.000 | 0.987 ± 0.003 | 20 | 1.000 | 23 |
| jcv-001 | 0.000 | 0.000 | 0.992 ± 0.002 | 21 | 1.000 | 22 |
| spooff-000 | 0.000 | 0.000 | 0.994 ± 0.002 | 22 | 1.000 | 25 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0.0003 | 23 | 1.000 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.377 | 4 |
| aware-001 | 0.151 | 0.035 | 1 ± 0 | 24 | 0.657 | 11 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.806 | 15 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.495 | 6 |

**Table 46.** PA Type 8 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-000 | 0.000 | 0.000 | 0.009 ± 0.005 | 1 | 0.006 | 1 |
| onfido-001 | 0.000 | 0.000 | 0.017 ± 0.007 | 2 | 0.020 | 5 |
| kakao-001 | 0.000 | 0.000 | 0.018 ± 0.007 | 3 | 0.013 | 2 |
| onfido-000 | 0.000 | 0.000 | 0.024 ± 0.008 | 4 | 0.019 | 4 |
| aware-002 | 0.000 | 0.000 | 0.08 ± 0.01 | 5 | 0.075 | 7 |
| kasikornlabs-000 | 0.000 | 0.000 | 0.09 ± 0.01 | 6 | 0.126 | 9 |
| neurotechnology-000 | 0.000 | 0.000 | 0.1 ± 0.02 | 7 | 0.095 | 8 |
| kasikornlabs-001 | 0.000 | 0.000 | 0.15 ± 0.02 | 8 | 0.141 | 10 |
| facedirect-002 | 0.000 | 0.000 | 0.47 ± 0.03 | 9 | 1.000 | 25 |
| cyberlink-002 | 0.000 | 0.000 | 0.51 ± 0.03 | 10 | 0.067 | 6 |
| facedirect-001 | 0.000 | 0.000 | 0.86 ± 0.02 | 11 | 0.967 | 16 |
| cubox-001 | 0.000 | 0.000 | 0.88 ± 0.02 | 12 | 0.893 | 15 |
| cubox-000 | 0.000 | 0.000 | 0.9 ± 0.02 | 13 | 0.806 | 14 |
| trueface-000 | 0.000 | 0.000 | 0.972 ± 0.008 | 14 | 1.000 | 25 |
| jcv-001 | 0.000 | 0.000 | 0.986 ± 0.006 | 15 | 0.989 | 20 |
| griaule-000 | 0.000 | 0.000 | 0.989 ± 0.005 | 16 | 0.998 | 22 |
| spooff-000 | 0.000 | 0.000 | 0.99 ± 0.005 | 17 | 1.000 | 25 |
| cyberlink-001 | 0.004 | 0.001 | 0.991 ± 0.005 | 18 | 1.000 | 23 |
| griaule-001 | 0.000 | 0.000 | 0.992 ± 0.005 | 19 | 0.989 | 21 |
| rankone-000 | 0.000 | 0.000 | 0.996 ± 0.003 | 20 | 0.967 | 16 |
| rankone-001 | 0.000 | 0.000 | 0.996 ± 0.003 | 20 | 0.967 | 16 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 22 | 1.000 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.015 | 3 |
| aware-001 | 0.114 | 0.035 | 1 ± 0 | 22 | 0.978 | 19 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.224 | 11 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.696 | 13 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 22 | 0.678 | 12 |

**Table 47.** PA Type 8 (zoomed) - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| onfido-001 | 0.003 | 0.000 | 0.06 ± 0.01 | 1 | 0.096 | 2 |
| onfido-000 | 0.003 | 0.000 | 0.07 ± 0.01 | 2 | 0.219 | 4 |
| kakao-000 | 0.000 | 0.000 | 0.07 ± 0.01 | 3 | 0.099 | 3 |
| kakao-001 | 0.000 | 0.000 | 0.12 ± 0.02 | 4 | 0.052 | 1 |
| kasikornlabs-000 | 0.001 | 0.000 | 0.12 ± 0.02 | 5 | 0.574 | 7 |
| kasikornlabs-001 | 0.001 | 0.000 | 0.22 ± 0.02 | 6 | 0.628 | 9 |
| facedirect-002 | 0.000 | 0.000 | 0.3 ± 0.02 | 7 | 1.000 | 23 |
| neurotechnology-000 | 0.000 | 0.000 | 0.3 ± 0.02 | 8 | 1.000 | 23 |
| aware-002 | 0.000 | 0.000 | 0.31 ± 0.02 | 9 | 0.329 | 6 |
| facedirect-001 | 0.000 | 0.000 | 0.83 ± 0.02 | 10 | 0.924 | 14 |
| cubox-000 | 0.000 | 0.000 | 0.89 ± 0.02 | 11 | 0.806 | 11 |
| cyberlink-002 | 0.000 | 0.000 | 0.9 ± 0.02 | 12 | 0.984 | 17 |
| cubox-001 | 0.000 | 0.000 | 0.94 ± 0.01 | 13 | 0.893 | 13 |
| spooff-000 | 0.000 | 0.000 | 0.96 ± 0.01 | 14 | 1.000 | 23 |
| trueface-000 | 0.003 | 0.000 | 0.989 ± 0.005 | 15 | 1.000 | 23 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.005 | 16 | 0.989 | 18 |
| rankone-000 | 0.000 | 0.000 | 0.992 ± 0.005 | 17 | 0.967 | 15 |
| rankone-001 | 0.000 | 0.000 | 0.992 ± 0.005 | 17 | 0.967 | 15 |
| griaule-000 | 0.000 | 0.000 | 0.994 ± 0.004 | 19 | 0.998 | 21 |
| griaule-001 | 0.000 | 0.000 | 0.994 ± 0.004 | 19 | 0.989 | 19 |
| cyberlink-001 | 0.002 | 0.001 | 0.998 ± 0.002 | 21 | 1.000 | 22 |
| papago-001 | 0.000 | 0.000 | 0.999 ± 0.002 | 22 | 0.696 | 10 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 23 | 1.000 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.813 | 12 |
| aware-001 | 0.117 | 0.035 | 1 ± 0 | 23 | 0.989 | 19 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.224 | 5 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 23 | 0.628 | 8 |

**Table 48.** PA Type 9 - Use Case: detectEvasionPA - Media Type: stills

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kasikornlabs-000 | 0.005 | 0.000 | 0.052 ± 0.005 | 1 | 0.055 | 3 |
| kasikornlabs-001 | 0.005 | 0.000 | 0.063 ± 0.006 | 2 | 0.095 | 5 |
| onfido-000 | 0.006 | 0.000 | 0.068 ± 0.006 | 3 | 0.146 | 6 |
| kakao-001 | 0.000 | 0.000 | 0.107 ± 0.007 | 4 | 0.242 | 10 |
| onfido-001 | 0.006 | 0.000 | 0.135 ± 0.008 | 5 | 0.195 | 8 |
| kakao-000 | 0.000 | 0.000 | 0.26 ± 0.01 | 6 | 0.761 | 16 |
| rankone-000 | 0.000 | 0.000 | 0.27 ± 0.01 | 7 | 0.580 | 13 |
| rankone-001 | 0.000 | 0.000 | 0.27 ± 0.01 | 7 | 0.580 | 13 |
| aware-002 | 0.000 | 0.000 | 0.34 ± 0.01 | 9 | 0.161 | 7 |
| cyberlink-002 | 0.000 | 0.000 | 0.41 ± 0.01 | 10 | 0.027 | 1 |
| facedirect-002 | 0.000 | 0.000 | 0.44 ± 0.01 | 11 | 1.000 | 25 |
| neurotechnology-000 | 0.001 | 0.000 | 0.53 ± 0.01 | 12 | 0.442 | 12 |
| facedirect-001 | 0.000 | 0.000 | 0.836 ± 0.009 | 13 | 0.913 | 17 |
| cubox-000 | 0.000 | 0.000 | 0.907 ± 0.007 | 14 | 0.967 | 19 |
| cyberlink-001 | 0.001 | 0.001 | 0.907 ± 0.007 | 15 | 0.322 | 11 |
| trueface-000 | 0.000 | 0.000 | 0.947 ± 0.006 | 16 | 1.000 | 25 |
| griaule-000 | 0.000 | 0.000 | 0.953 ± 0.005 | 17 | 0.978 | 20 |
| griaule-001 | 0.000 | 0.000 | 0.972 ± 0.004 | 18 | 0.945 | 18 |
| cubox-001 | 0.000 | 0.000 | 0.974 ± 0.004 | 19 | 1.000 | 22 |
| papago-001 | 0.000 | 0.000 | 0.988 ± 0.003 | 20 | 1.000 | 22 |
| jcv-001 | 0.000 | 0.000 | 0.99 ± 0.002 | 21 | 1.000 | 21 |
| spooff-000 | 0.000 | 0.000 | 0.993 ± 0.002 | 22 | 1.000 | 25 |
| alchera-000 | 0.000 | 0.000 | 0.998 ± 0.001 | 23 | 1.000 | 22 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.034 | 2 |
| aware-001 | 0.096 | 0.035 | 1 ± 0 | 24 | 0.066 | 4 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.657 | 15 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 24 | 0.200 | 9 |

**Table 49.** PA Type 1 - Use Case: detectEvasionPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0 | 0.000 | 0.14 ± 0.09 | 1 | 0.072 | 2 |
| kasikornlabs-000 | 0 | 0.000 | 0.3 ± 0.1 | 2 | 0.418 | 4 |
| kakao-000 | 0 | 0.000 | 0.3 ± 0.1 | 2 | 0.255 | 3 |
| cyberlink-002 | 0 | 0.000 | 0.4 ± 0.1 | 4 | 0.050 | 1 |
| kasikornlabs-001 | 0 | 0.000 | 0.4 ± 0.1 | 4 | 0.468 | 6 |
| onfido-000 | 0 | 0.000 | 0.6 ± 0.1 | 6 | 0.853 | 13 |
| neurotechnology-000 | 0 | 0.000 | 0.6 ± 0.1 | 6 | 0.535 | 7 |
| onfido-001 | 0 | 0.000 | 0.7 ± 0.1 | 8 | 0.805 | 12 |
| aware-001 | 0 | 0.002 | 0.7 ± 0.1 | 8 | 0.636 | 9 |
| rankone-000 | 0 | 0.000 | 0.8 ± 0.1 | 10 | 0.924 | 17 |
| rankone-001 | 0 | 0.000 | 0.8 ± 0.1 | 10 | 0.924 | 17 |
| facedirect-001 | 0 | 0.000 | 0.91 ± 0.07 | 12 | 0.913 | 15 |
| aware-002 | 0 | 0.000 | 0.91 ± 0.08 | 13 | 0.743 | 10 |
| cubox-000 | 0 | 0.000 | 0.93 ± 0.06 | 14 | 0.853 | 13 |
| cyberlink-001 | 0 | 0.000 | 0.93 ± 0.06 | 14 | 0.779 | 11 |
| facedirect-002 | 0 | 0.000 | 0.96 ± 0.04 | 16 | 1.000 | 23 |
| jcv-001 | 0 | 0.000 | 0.98 ± 0.03 | 17 | 0.998 | 22 |
| trueface-000 | 0 | 0.000 | 0.98 ± 0.03 | 17 | 1.000 | 23 |
| alchera-000 | 0 | 0.000 | 1 ± 0 | 19 | 1.000 | 23 |
| alice-000 | 0 | 0.000 | 1 ± 0 | 19 | 0.463 | 5 |
| cubox-001 | 0 | 0.000 | 1 ± 0 | 19 | 0.944 | 19 |
| griaule-000 | 0 | 0.000 | 1 ± 0 | 19 | 0.976 | 20 |
| griaule-001 | 0 | 0.000 | 1 ± 0 | 19 | 0.987 | 21 |
| neurotechnology-001 | 0 | 0.000 | 1 ± 0 | 19 | 0.913 | 15 |
| papago-001 | 0 | 0.000 | 1 ± 0 | 19 | 1.000 | 23 |
| spooff-000 | 0 | 0.000 | 1 ± 0 | 19 | 1.000 | 23 |
| uxlabs-001 | 0 | 0.000 | 1 ± 0 | 19 | 0.567 | 8 |

**Table 50.** PA Type 3 - Use Case: detectEvasionPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| cyberlink-002 | 0 | 0.000 | 0 ± 0 | 1 | 0.006 | 1 |
| kasikornlabs-000 | 0 | 0.000 | 0.1 ± 0.2 | 2 | 0.013 | 2 |
| kasikornlabs-001 | 0 | 0.000 | 0.1 ± 0.2 | 2 | 0.059 | 9 |
| onfido-000 | 0 | 0.000 | 0.1 ± 0.2 | 2 | 0.013 | 2 |
| onfido-001 | 0 | 0.000 | 0.1 ± 0.2 | 2 | 0.035 | 5 |
| aware-001 | 0 | 0.002 | 0.2 ± 0.2 | 6 | 0.024 | 4 |
| aware-002 | 0 | 0.000 | 0.4 ± 0.3 | 7 | 0.080 | 11 |
| kakao-001 | 0 | 0.000 | 0.4 ± 0.3 | 7 | 0.035 | 5 |
| neurotechnology-000 | 0 | 0.000 | 0.4 ± 0.3 | 7 | 0.139 | 12 |
| kakao-000 | 0 | 0.000 | 0.5 ± 0.3 | 10 | 0.050 | 8 |
| facedirect-001 | 0 | 0.000 | 0.8 ± 0.2 | 11 | 0.046 | 7 |
| rankone-000 | 0 | 0.000 | 0.9 ± 0.2 | 12 | 0.779 | 17 |
| rankone-001 | 0 | 0.000 | 0.9 ± 0.2 | 12 | 0.779 | 17 |
| alchera-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.998 | 23 |
| alice-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.063 | 10 |
| cubox-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.976 | 20 |
| cubox-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.998 | 23 |
| cyberlink-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.230 | 13 |
| facedirect-002 | 0 | 0.000 | 1 ± 0 | 14 | 0.991 | 22 |
| griaule-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.636 | 16 |
| griaule-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.987 | 21 |
| jcv-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.942 | 19 |
| neurotechnology-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.554 | 14 |
| papago-001 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 25 |
| spooff-000 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 25 |
| trueface-000 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 25 |
| uxlabs-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.561 | 15 |

**Table 51.** PA Type 5 - Use Case: detectEvasionPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kakao-001 | 0.00 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kakao-000 | 0.00 | 0.000 | 0.02 ± 0.03 | 2 | 0.011 | 2 |
| facedirect-002 | 0.00 | 0.000 | 0.4 ± 0.1 | 3 | 1.000 | 23 |
| griaule-000 | 0.00 | 0.000 | 0.5 ± 0.1 | 4 | 0.987 | 18 |
| griaule-001 | 0.00 | 0.000 | 0.6 ± 0.1 | 5 | 0.944 | 16 |
| cyberlink-002 | 0.00 | 0.000 | 0.7 ± 0.1 | 6 | 0.621 | 5 |
| cyberlink-001 | 0.00 | 0.000 | 0.8 ± 0.1 | 7 | 0.872 | 13 |
| aware-002 | 0.00 | 0.000 | 0.8 ± 0.1 | 7 | 0.665 | 6 |
| onfido-000 | 0.00 | 0.000 | 0.8 ± 0.1 | 7 | 0.844 | 10 |
| neurotechnology-000 | 0.00 | 0.000 | 0.88 ± 0.09 | 10 | 0.883 | 14 |
| onfido-001 | 0.00 | 0.000 | 0.9 ± 0.09 | 11 | 0.712 | 8 |
| trueface-000 | 0.00 | 0.000 | 0.92 ± 0.07 | 12 | 1.000 | 23 |
| aware-001 | 0.02 | 0.002 | 0.96 ± 0.05 | 13 | 0.113 | 4 |
| cubox-001 | 0.00 | 0.000 | 0.96 ± 0.05 | 13 | 0.987 | 18 |
| kasikornlabs-000 | 0.00 | 0.000 | 0.96 ± 0.05 | 13 | 0.998 | 20 |
| kasikornlabs-001 | 0.00 | 0.000 | 0.96 ± 0.05 | 13 | 0.998 | 20 |
| cubox-000 | 0.00 | 0.000 | 0.98 ± 0.03 | 17 | 0.976 | 17 |
| rankone-000 | 0.00 | 0.000 | 0.98 ± 0.03 | 17 | 0.853 | 11 |
| rankone-001 | 0.00 | 0.000 | 0.98 ± 0.03 | 17 | 0.853 | 11 |
| spooff-000 | 0.00 | 0.000 | 0.98 ± 0.03 | 17 | 0.779 | 9 |
| alchera-000 | 0.00 | 0.000 | 1 ± 0 | 21 | 1.000 | 23 |
| alice-000 | 0.00 | 0.000 | 1 ± 0 | 21 | 0.688 | 7 |
| facedirect-001 | 0.00 | 0.000 | 1 ± 0 | 21 | 0.998 | 20 |
| jcv-001 | 0.00 | 0.000 | 1 ± 0 | 21 | 1.000 | 23 |
| neurotechnology-001 | 0.00 | 0.000 | 1 ± 0 | 21 | 0.892 | 15 |
| papago-001 | 0.00 | 0.000 | 1 ± 0 | 21 | 1.000 | 23 |
| uxlabs-001 | 0.00 | 0.000 | 1 ± 0 | 21 | 0.063 | 3 |

**Table 52.** PA Type 8 - Use Case: detectEvasionPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kasikornlabs-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kasikornlabs-001 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| neurotechnology-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| onfido-000 | 0 | 0.000 | 0 ± 0 | 1 | 0.004 | 4 |
| onfido-001 | 0 | 0.000 | 0.02 ± 0.03 | 5 | 0.011 | 5 |
| kakao-001 | 0 | 0.000 | 0.09 ± 0.07 | 6 | 0.087 | 8 |
| kakao-000 | 0 | 0.000 | 0.11 ± 0.08 | 7 | 0.177 | 12 |
| cyberlink-002 | 0 | 0.000 | 0.4 ± 0.1 | 8 | 0.022 | 6 |
| facedirect-002 | 0 | 0.000 | 0.6 ± 0.1 | 9 | 0.991 | 22 |
| facedirect-001 | 0 | 0.000 | 0.8 ± 0.1 | 10 | 0.987 | 21 |
| aware-002 | 0 | 0.000 | 0.8 ± 0.1 | 10 | 0.370 | 13 |
| cubox-001 | 0 | 0.000 | 0.96 ± 0.05 | 12 | 0.385 | 14 |
| trueface-000 | 0 | 0.000 | 0.98 ± 0.03 | 13 | 1.000 | 23 |
| alchera-000 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 23 |
| alice-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.065 | 7 |
| aware-001 | 0 | 0.002 | 1 ± 0 | 14 | 0.600 | 15 |
| cubox-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.095 | 10 |
| cyberlink-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.872 | 17 |
| griaule-000 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 23 |
| griaule-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.797 | 16 |
| jcv-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.985 | 20 |
| neurotechnology-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.154 | 11 |
| papago-001 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 23 |
| rankone-000 | 0 | 0.000 | 1 ± 0 | 14 | 0.944 | 18 |
| rankone-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.944 | 18 |
| spooff-000 | 0 | 0.000 | 1 ± 0 | 14 | 1.000 | 23 |
| uxlabs-001 | 0 | 0.000 | 1 ± 0 | 14 | 0.093 | 9 |

**Table 53.** PA Type 9 - Use Case: detectEvasionPA - Media Type: videos

| Algorithm | APNRR | BPNRR | (Convenience) APCER @ BPCER=0.01 | Rank | (Security) BPCER @ APCER=0.01 | Rank |
|---|---|---|---|---|---|---|
| kasikornlabs-000 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kasikornlabs-001 | 0.000 | 0.000 | 0 ± 0 | 1 | 0.002 | 1 |
| kakao-001 | 0.000 | 0.000 | 0.05 ± 0.07 | 3 | 0.015 | 3 |
| onfido-000 | 0.000 | 0.000 | 0.1 ± 0.1 | 4 | 0.301 | 11 |
| neurotechnology-000 | 0.000 | 0.000 | 0.2 ± 0.1 | 5 | 0.084 | 7 |
| kakao-000 | 0.000 | 0.000 | 0.3 ± 0.1 | 6 | 0.309 | 12 |
| onfido-001 | 0.000 | 0.000 | 0.4 ± 0.2 | 7 | 0.428 | 15 |
| cyberlink-001 | 0.000 | 0.000 | 0.6 ± 0.2 | 8 | 0.136 | 9 |
| aware-001 | 0.053 | 0.002 | 0.7 ± 0.1 | 9 | 0.041 | 4 |
| rankone-000 | 0.000 | 0.000 | 0.7 ± 0.1 | 9 | 0.403 | 13 |
| rankone-001 | 0.000 | 0.000 | 0.7 ± 0.1 | 9 | 0.403 | 13 |
| cubox-001 | 0.000 | 0.000 | 0.8 ± 0.1 | 12 | 0.812 | 19 |
| cyberlink-002 | 0.000 | 0.000 | 0.8 ± 0.1 | 12 | 0.052 | 5 |
| aware-002 | 0.000 | 0.000 | 0.8 ± 0.1 | 12 | 0.719 | 18 |
| facedirect-001 | 0.000 | 0.000 | 0.8 ± 0.1 | 12 | 0.480 | 16 |
| facedirect-002 | 0.000 | 0.000 | 0.8 ± 0.1 | 12 | 0.991 | 22 |
| cubox-000 | 0.000 | 0.000 | 0.9 ± 0.1 | 17 | 0.862 | 20 |
| trueface-000 | 0.000 | 0.000 | 0.95 ± 0.07 | 18 | 1.000 | 25 |
| alchera-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.998 | 23 |
| alice-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.071 | 6 |
| griaule-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.955 | 21 |
| griaule-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.665 | 17 |
| jcv-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.998 | 23 |
| neurotechnology-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.234 | 10 |
| papago-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 25 |
| spooff-000 | 0.000 | 0.000 | 1 ± 0 | 19 | 1.000 | 25 |
| uxlabs-001 | 0.000 | 0.000 | 1 ± 0 | 19 | 0.126 | 8 |

**Fig. 40.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA stills.

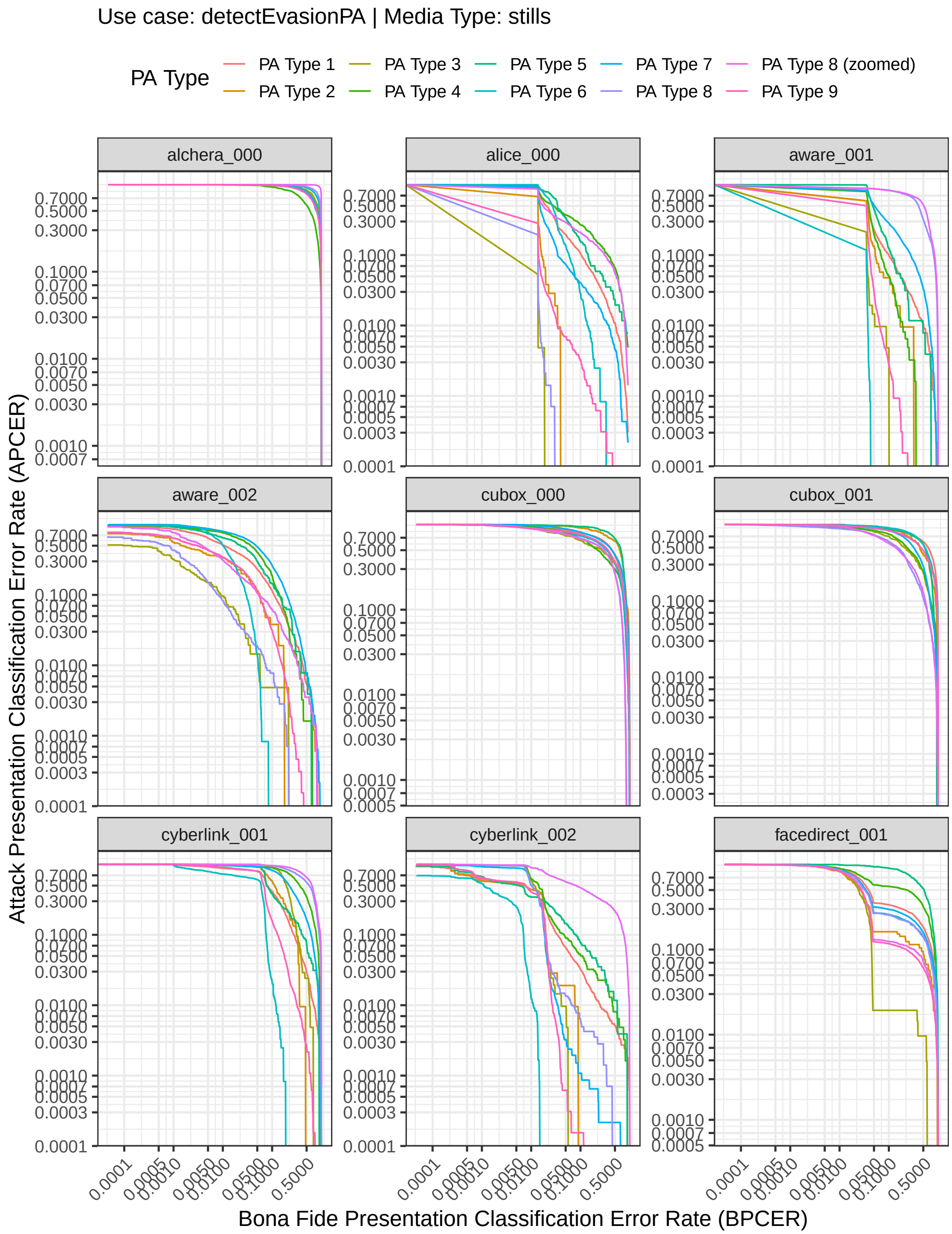


**Fig. 41.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA stills.

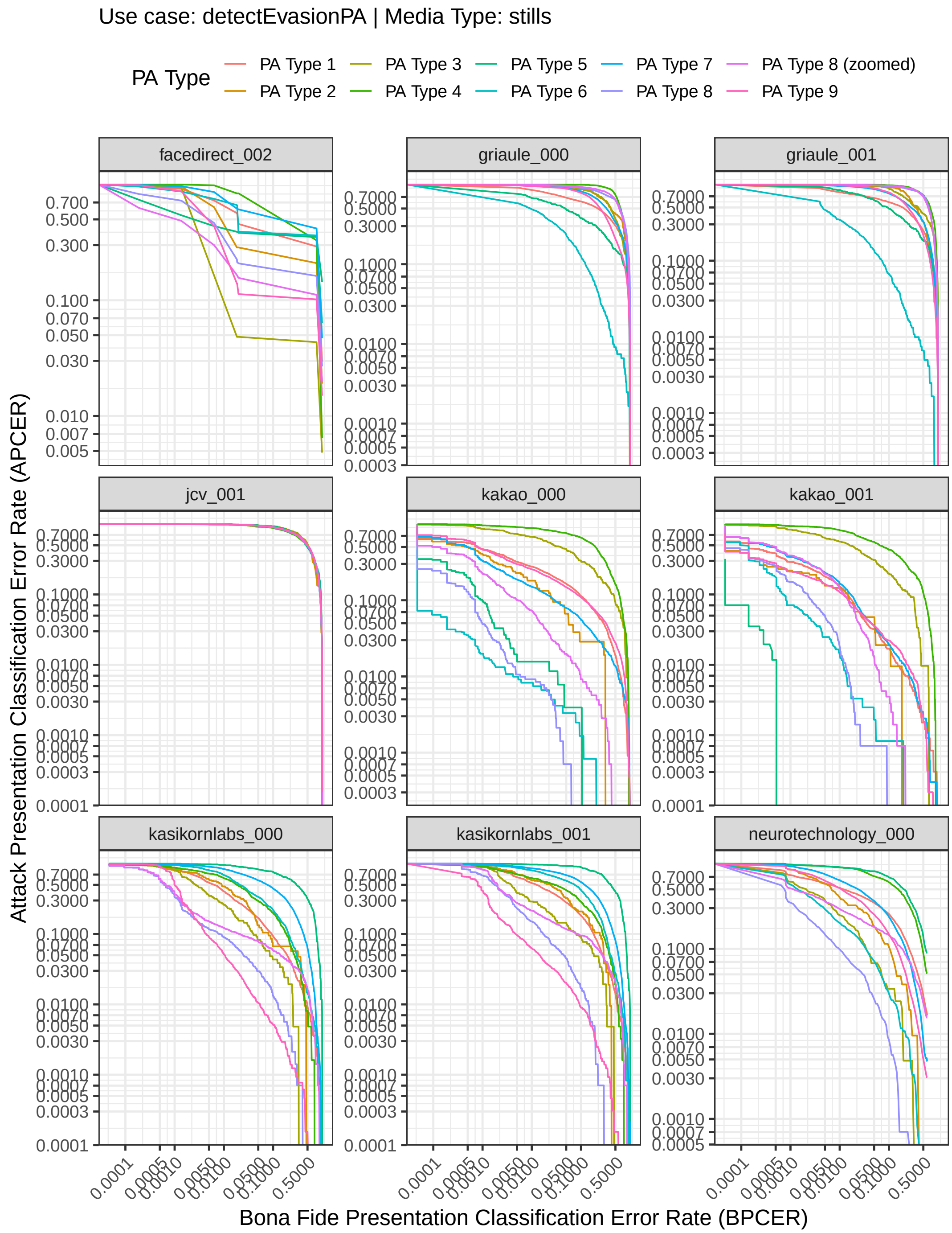


**Fig. 42.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA stills.

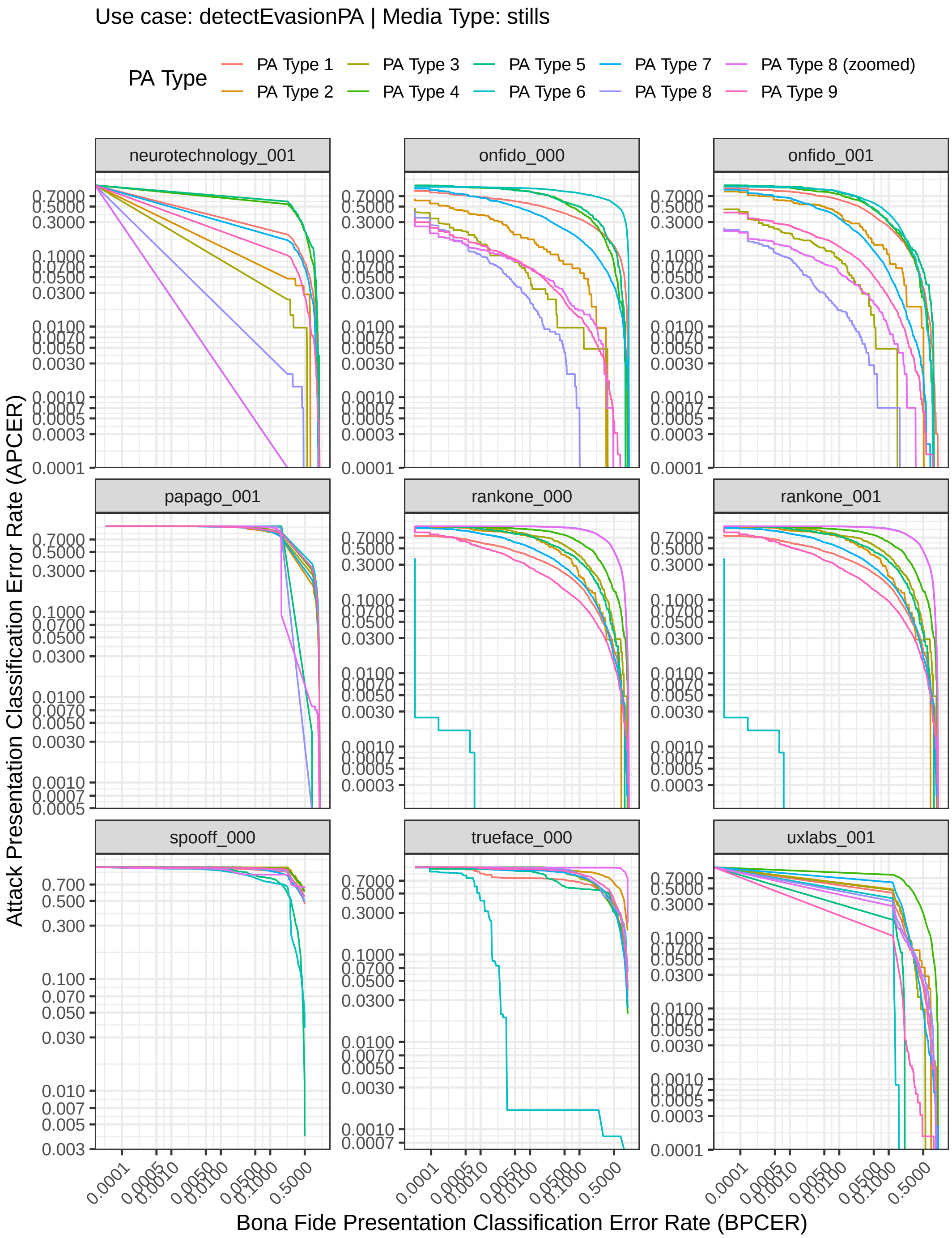


**Fig. 43.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA videos.

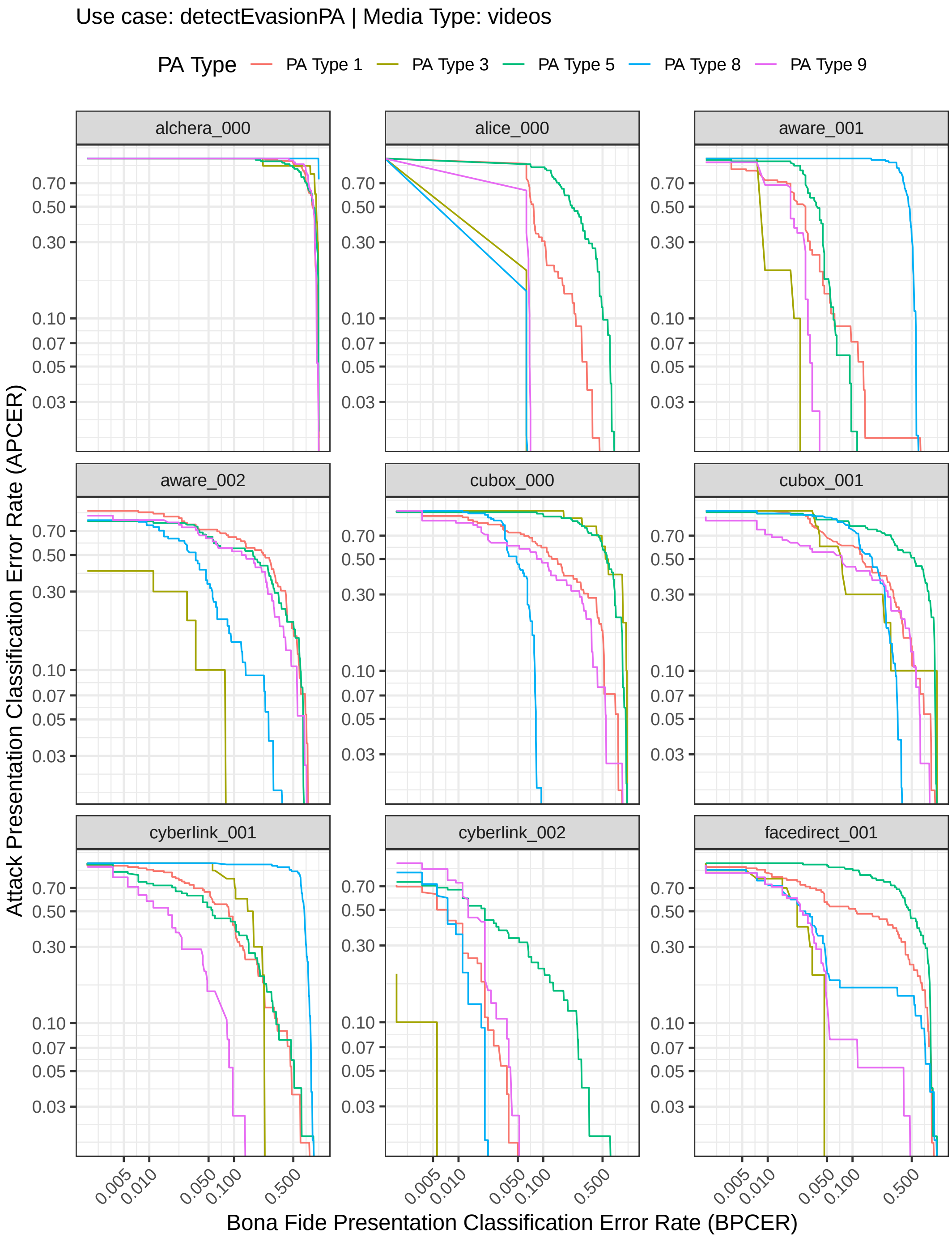


**Fig. 44.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA videos.

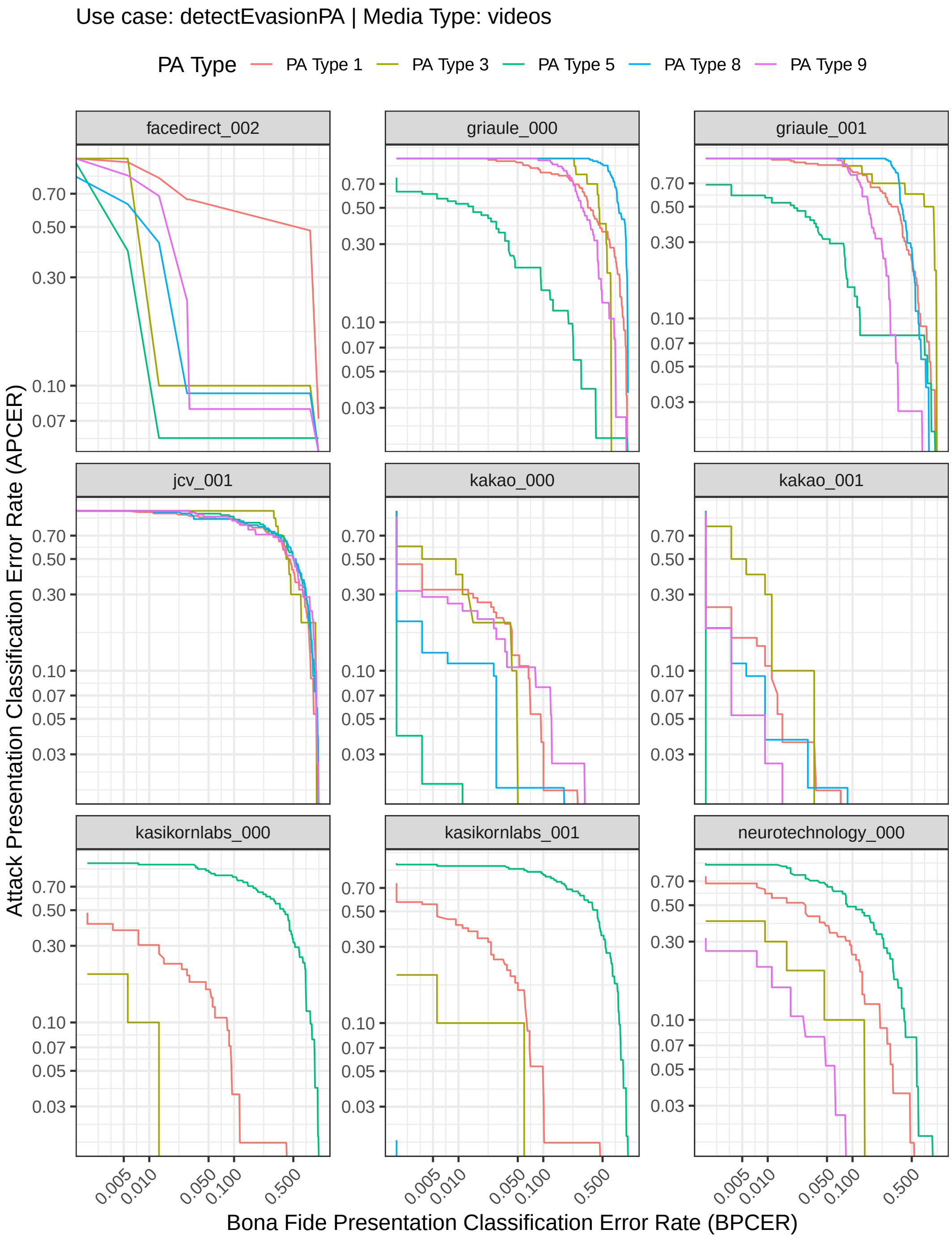
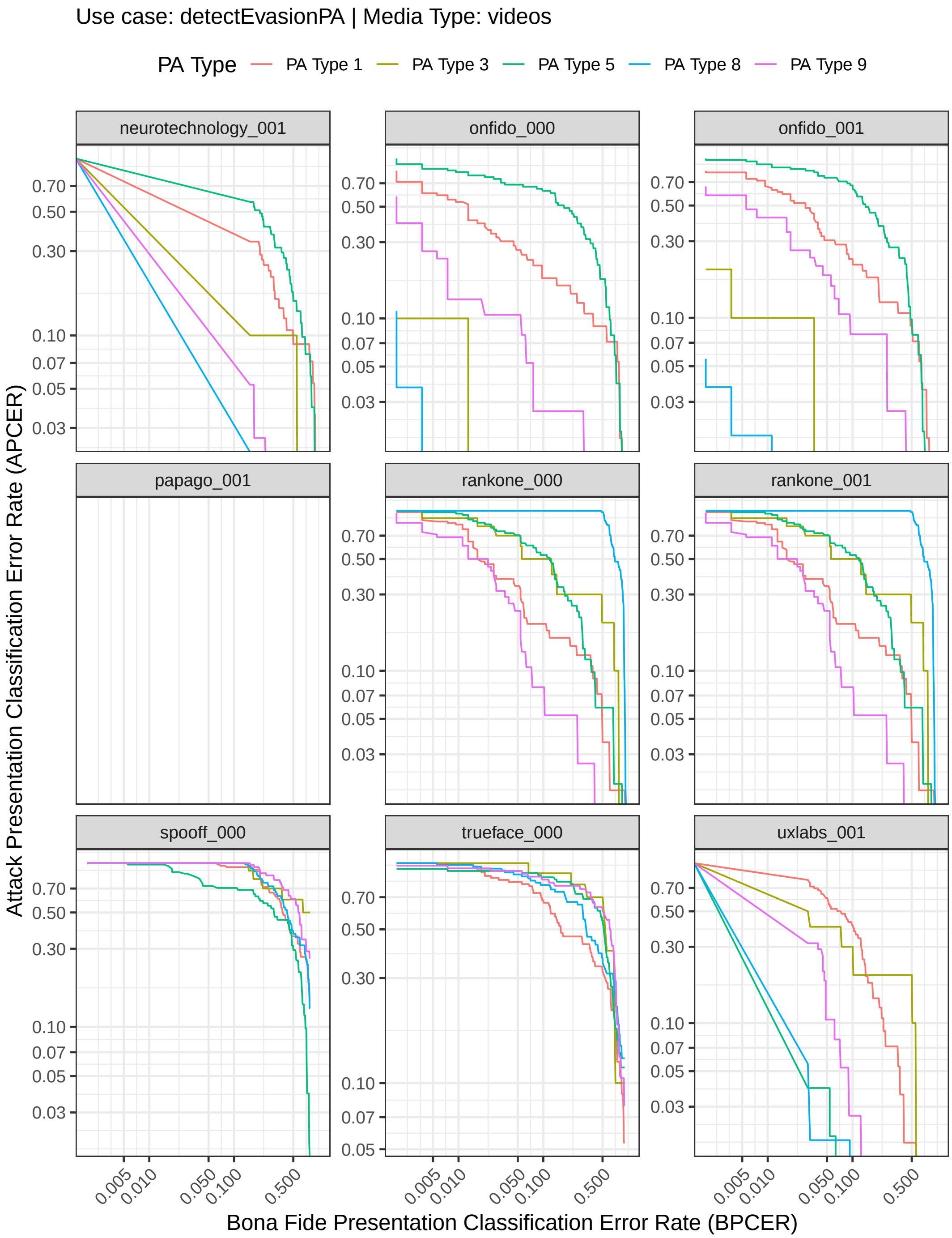


**Fig. 45.** This plot presents detection error tradeoff (DET) curves for PAD performance across different types of evasion PA videos.



## Appendix B. Stills vs. Videos

### Appendix B.1. Impersonation

**Table 54.** Use Case: detectImpersonationPA - Stills vs. Videos

| | (Convenience) APCER @ BPCER=0.01 | | | (Security) BPCER @ APCER=0.01 | |
|---|---|---|---|---|---|
| Algorithm | Stills | Videos | Algorithm | Stills | Videos |
| alchera-000 | 1.00 | 1.00 | alchera-000 | 1.00 | 1.00 |
| alice-000 | 0.12 | 1.00 | alice-000 | 0.20 | 0.18 |
| alice-001 | 0.12 | 0.06 | alice-001 | 0.53 | 0.46 |
| aware-001 | 0.49 | 1.00 | aware-001 | 0.20 | 0.14 |
| aware-002 | 0.50 | 0.75 | aware-002 | 0.29 | 0.60 |
| biocube-001 | 0.94 | 0.82 | biocube-001 | 0.89 | 0.80 |
| biocube-002 | 0.92 | 0.82 | biocube-002 | 0.76 | 0.90 |
| cubox-000 | 0.94 | 0.96 | cubox-000 | 0.99 | 0.98 |
| cubox-001 | 1.00 | 0.97 | cubox-001 | 0.91 | 1.00 |
| cyberlink-001 | 0.03 | 0.03 | cyberlink-001 | 0.03 | 0.03 |
| cyberlink-002 | 0.00 | 0.00 | cyberlink-002 | 0.00 | 0.01 |
| facedirect-001 | 0.53 | 0.71 | facedirect-001 | 0.99 | 0.99 |
| facedirect-002 | 0.97 | 0.75 | facedirect-002 | 1.00 | 0.99 |
| facephi-000 | 1.00 | 0.11 | facephi-000 | 0.28 | 0.26 |
| facephi-001 | 1.00 | 0.19 | facephi-001 | 0.59 | 0.66 |
| griaule-000 | 0.23 | 0.25 | griaule-000 | 0.68 | 0.67 |
| griaule-001 | 0.40 | 0.63 | griaule-001 | 1.00 | 0.21 |
| hyperverge-001 | 0.13 | 0.11 | hyperverge-001 | 0.31 | 0.15 |
| hyperverge-002 | 0.14 | 0.18 | hyperverge-002 | 1.00 | 0.07 |
| id3-001 | 0.38 | 0.34 | id3-001 | 0.92 | 0.88 |
| idemia-010 | 0.50 | 0.30 | idemia-010 | 0.26 | 0.18 |
| idemia-011 | 0.23 | 0.20 | idemia-011 | 0.80 | 0.88 |
| idrnd-000 | 0.08 | 0.04 | idrnd-000 | 0.08 | 0.09 |
| idrnd-001 | 0.05 | 0.03 | idrnd-001 | 0.07 | 0.03 |
| idvisioncenter-001 | 0.59 | 0.25 | idvisioncenter-001 | 0.82 | 0.90 |
| idvisioncenter-002 | 0.82 | 0.59 | idvisioncenter-002 | 0.77 | 0.69 |
| iidentifii-000 | 0.09 | 0.08 | iidentifii-000 | 0.24 | 0.17 |
| incode-000 | 0.31 | 0.32 | incode-000 | 0.49 | 0.31 |
| incode-001 | 0.18 | 0.19 | incode-001 | 1.00 | 0.28 |
| innovatrics-001 | 0.24 | 0.19 | innovatrics-001 | 0.92 | 0.68 |
| innovatrics-002 | 0.47 | 0.18 | innovatrics-002 | 0.64 | 0.61 |
| intema-000 | 0.27 | 0.23 | intema-000 | 0.85 | 0.64 |

| | | | | | |
|---|---|---|---|---|---|
| intema-001 | 0.22 | 0.20 | intema-001 | 0.81 | 0.62 |
| iproov-000 | 0.05 | 1.00 | iproov-000 | 0.05 | 0.03 |
| iproov-001 | 0.05 | 0.03 | iproov-001 | 0.05 | 0.07 |
| jcv-001 | 0.19 | 1.00 | jcv-001 | 0.84 | 1.00 |
| jcv-002 | 0.22 | 1.00 | jcv-002 | 1.00 | 0.73 |
| kakao-000 | 0.15 | 0.14 | kakao-000 | 0.14 | 0.16 |
| kakao-001 | 0.01 | 0.04 | kakao-001 | 0.07 | 0.05 |
| kasikornlabs-000 | 0.10 | 0.04 | kasikornlabs-000 | 0.19 | 0.02 |
| kasikornlabs-001 | 0.27 | 0.06 | kasikornlabs-001 | 0.25 | 0.06 |
| mbsolutions-000 | 0.27 | 0.25 | mbsolutions-000 | 1.00 | 0.87 |
| mbsolutions-001 | 0.26 | 0.23 | mbsolutions-001 | 1.00 | 0.87 |
| meituan-000 | 0.26 | 0.15 | meituan-000 | 0.88 | 0.80 |
| meituan-001 | 0.24 | 0.23 | meituan-001 | 1.00 | 0.19 |
| mobbl-000 | 1.00 | 0.92 | mobbl-000 | 0.83 | 0.91 |
| mobbl-001 | 1.00 | 0.97 | mobbl-001 | 1.00 | 0.81 |
| neurotechnology-000 | 0.05 | 0.13 | neurotechnology-000 | 0.36 | 0.14 |
| neurotechnology-001 | 1.00 | 1.00 | neurotechnology-001 | 0.76 | 0.64 |
| nsensekorea-000 | 0.45 | 0.86 | nsensekorea-000 | 0.87 | 1.00 |
| nsensekorea-001 | 0.45 | 0.86 | nsensekorea-001 | 0.87 | 1.00 |
| onfido-000 | 0.06 | 0.11 | onfido-000 | 0.35 | 0.79 |
| onfido-001 | 0.14 | 0.15 | onfido-001 | 0.60 | 0.75 |
| papago-001 | 1.00 | 1.00 | papago-001 | 1.00 | 1.00 |
| pxl-000 | 1.00 | 1.00 | pxl-000 | 1.00 | 1.00 |
| pxl-001 | 0.65 | 0.46 | pxl-001 | 0.40 | 0.68 |
| rankone-000 | 0.42 | 0.41 | rankone-000 | 0.23 | 0.08 |
| rankone-001 | 0.23 | 0.29 | rankone-001 | 0.27 | 0.20 |
| saffe-001 | 0.24 | 0.25 | saffe-001 | 0.80 | 0.79 |
| saffe-002 | 0.23 | 0.23 | saffe-002 | 0.78 | 0.65 |
| spooff-000 | 0.95 | 1.00 | spooff-000 | 0.86 | 0.83 |
| stcon-000 | 0.09 | 0.03 | stcon-000 | 0.55 | 0.19 |
| stcon-001 | 0.03 | 0.01 | stcon-001 | 0.05 | 0.01 |
| tech5-001 | 1.00 | 1.00 | tech5-001 | 1.00 | 1.00 |
| techsign-000 | 0.97 | 0.76 | techsign-000 | 0.93 | 0.76 |
| techsign-001 | 0.71 | 0.43 | techsign-001 | 0.71 | 0.33 |
| trueface-000 | 1.00 | 1.00 | trueface-000 | 0.65 | 0.83 |
| uxlabs-001 | 1.00 | 1.00 | uxlabs-001 | 0.53 | 0.57 |
| veridas-001 | 0.44 | 0.41 | veridas-001 | 0.21 | 0.13 |
| veridas-002 | 0.50 | 0.52 | veridas-002 | 0.28 | 0.08 |
| verigram-000 | 1.00 | 0.39 | verigram-000 | 0.73 | 0.81 |
| verigram-001 | 0.69 | 0.32 | verigram-001 | 0.92 | 0.67 |
| verihubs-inteligensia-000 | 0.28 | 0.33 | verihubs-inteligensia-000 | 0.50 | 0.60 |
| verihubs-inteligensia-001 | 0.13 | 0.29 | verihubs-inteligensia-001 | 0.48 | 0.26 |
| vida-001 | 0.73 | 0.72 | vida-001 | 0.64 | 0.84 |

| | | | | | |
|---|---|---|---|---|---|
| vida-002 | 0.23 | 0.18 | vida-002 | 0.16 | 0.23 |
| visteam-001 | 1.00 | 0.68 | visteam-001 | 0.77 | 0.92 |
| visteam-002 | 0.85 | 0.84 | visteam-002 | 0.18 | 0.26 |
| yoonik-001 | 0.51 | 0.52 | yoonik-001 | 0.72 | 0.76 |
| yoonik-002 | 0.95 | 1.00 | yoonik-002 | 0.53 | 0.74 |
| yoti-001 | 1.00 | 1.00 | yoti-001 | 1.00 | 0.22 |
| yoti-002 | 1.00 | 1.00 | yoti-002 | 1.00 | 0.24 |

**Fig. 46.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

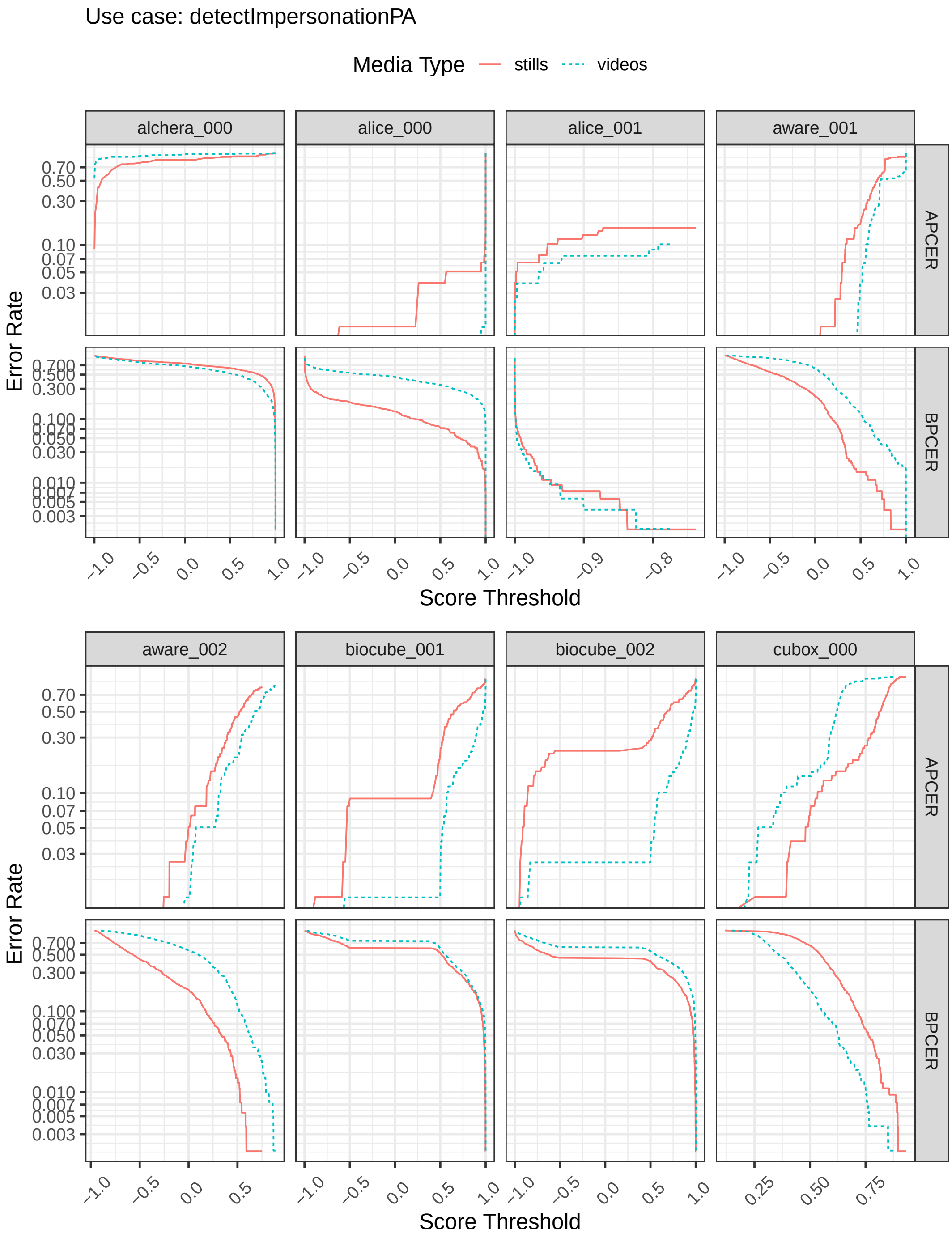


**Fig. 47.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

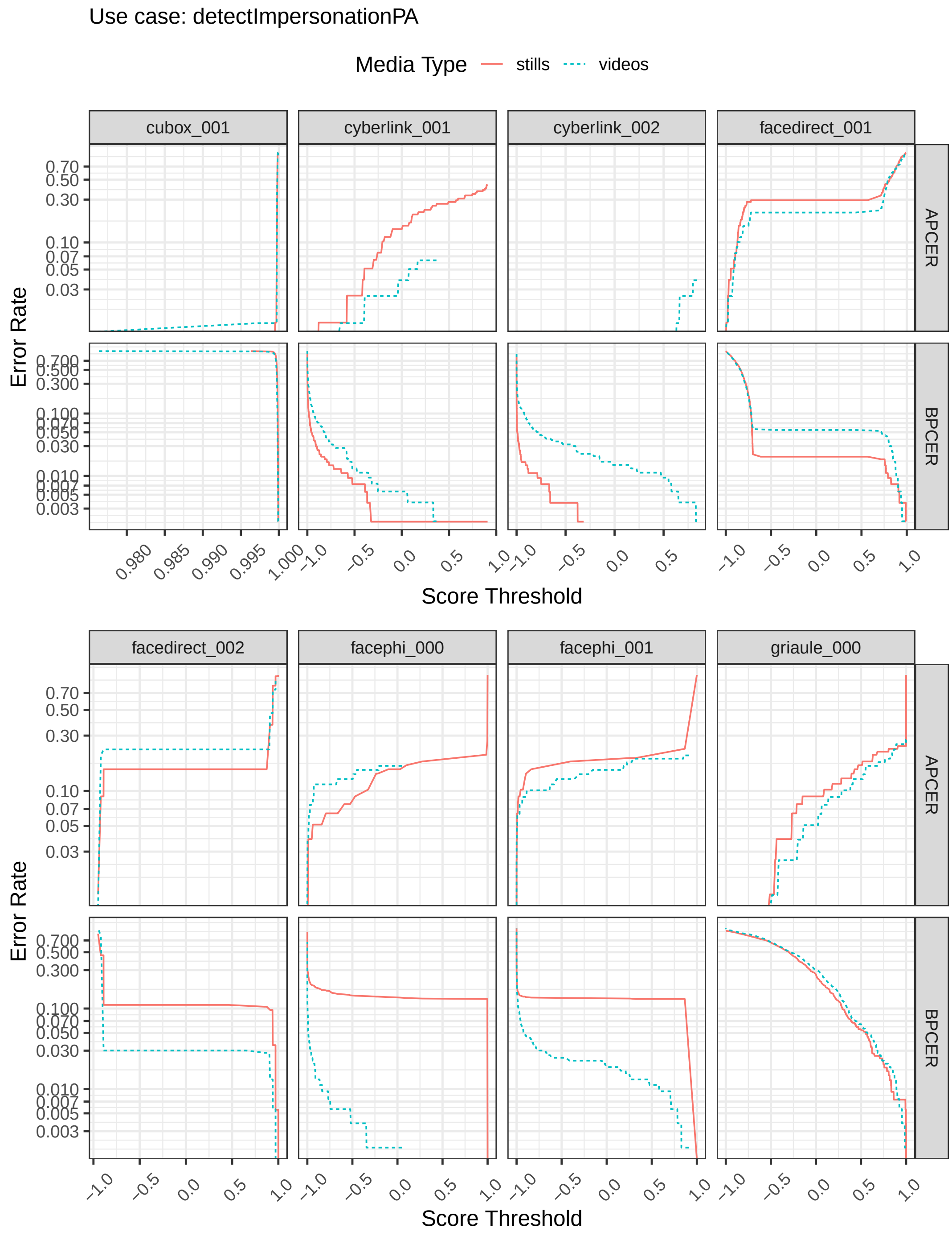


**Fig. 48.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

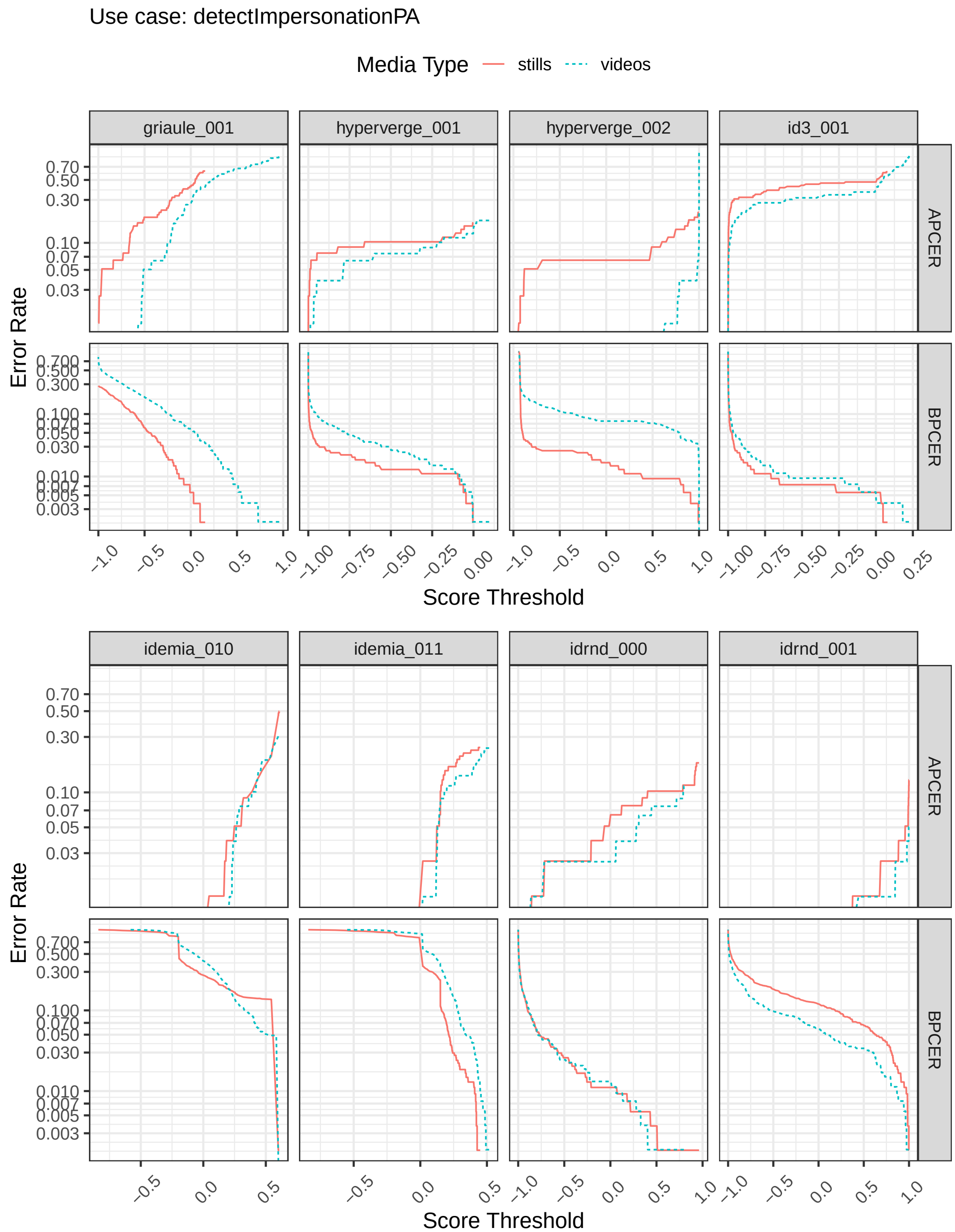


**Fig. 49.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

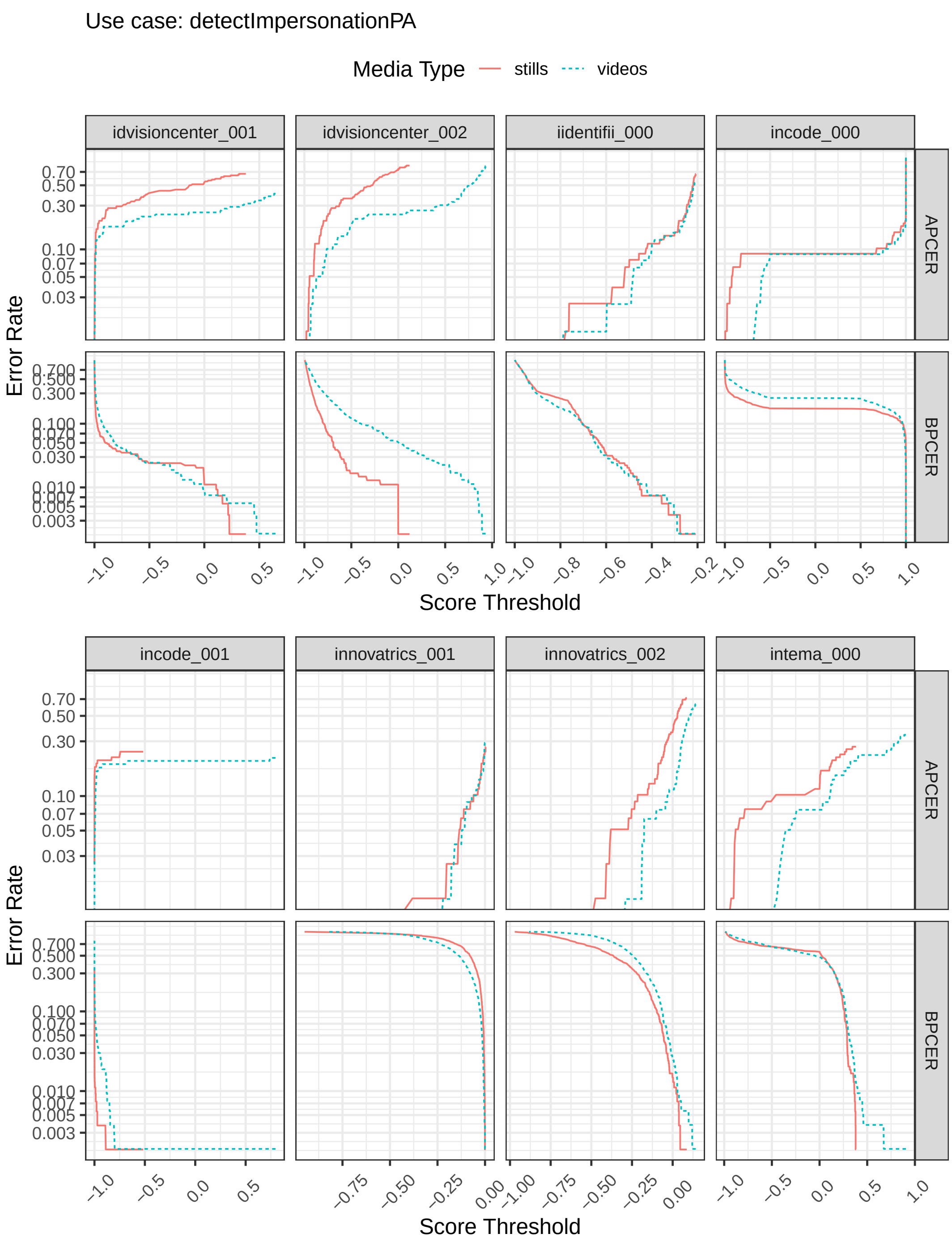


**Fig. 50.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

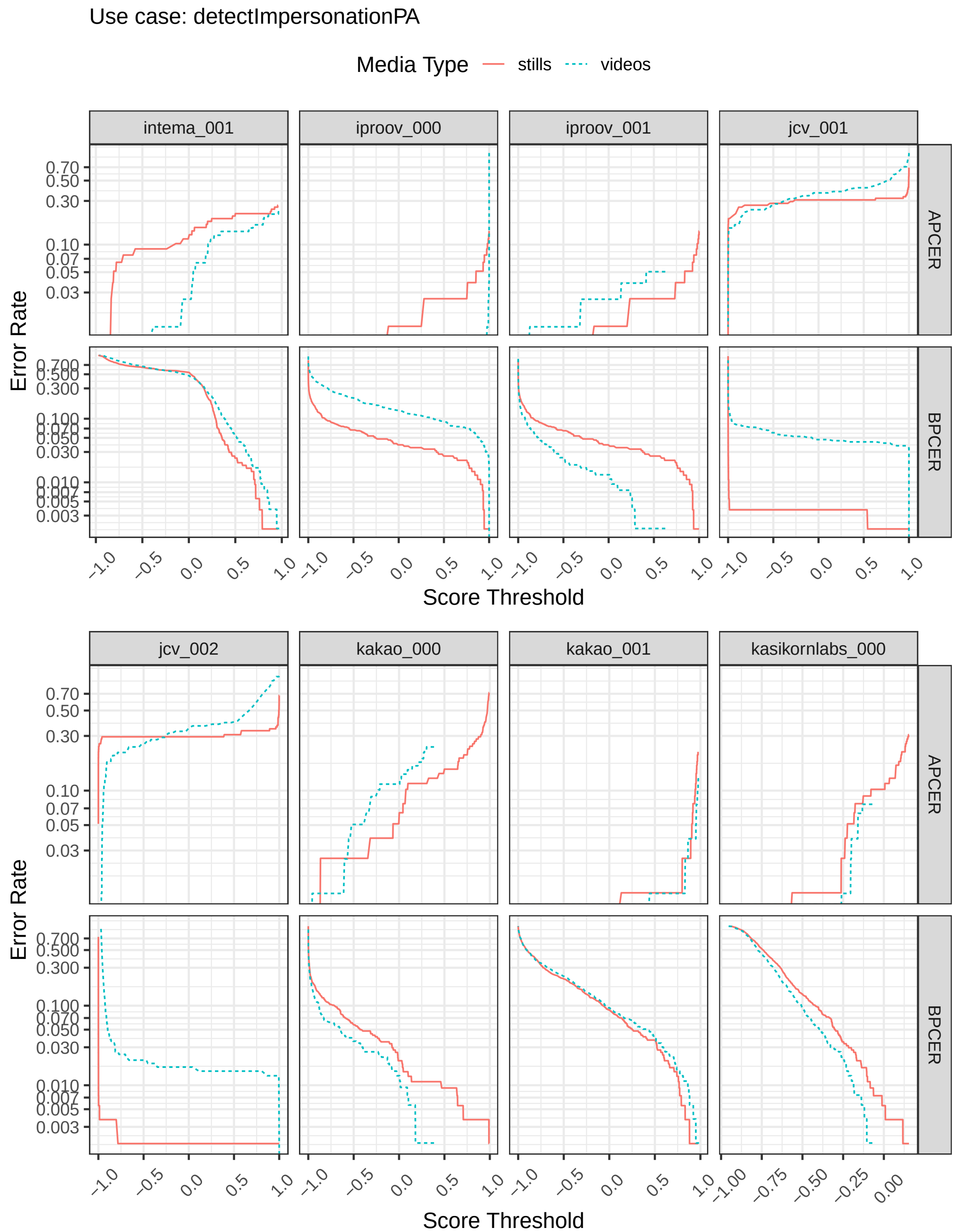


**Fig. 51.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

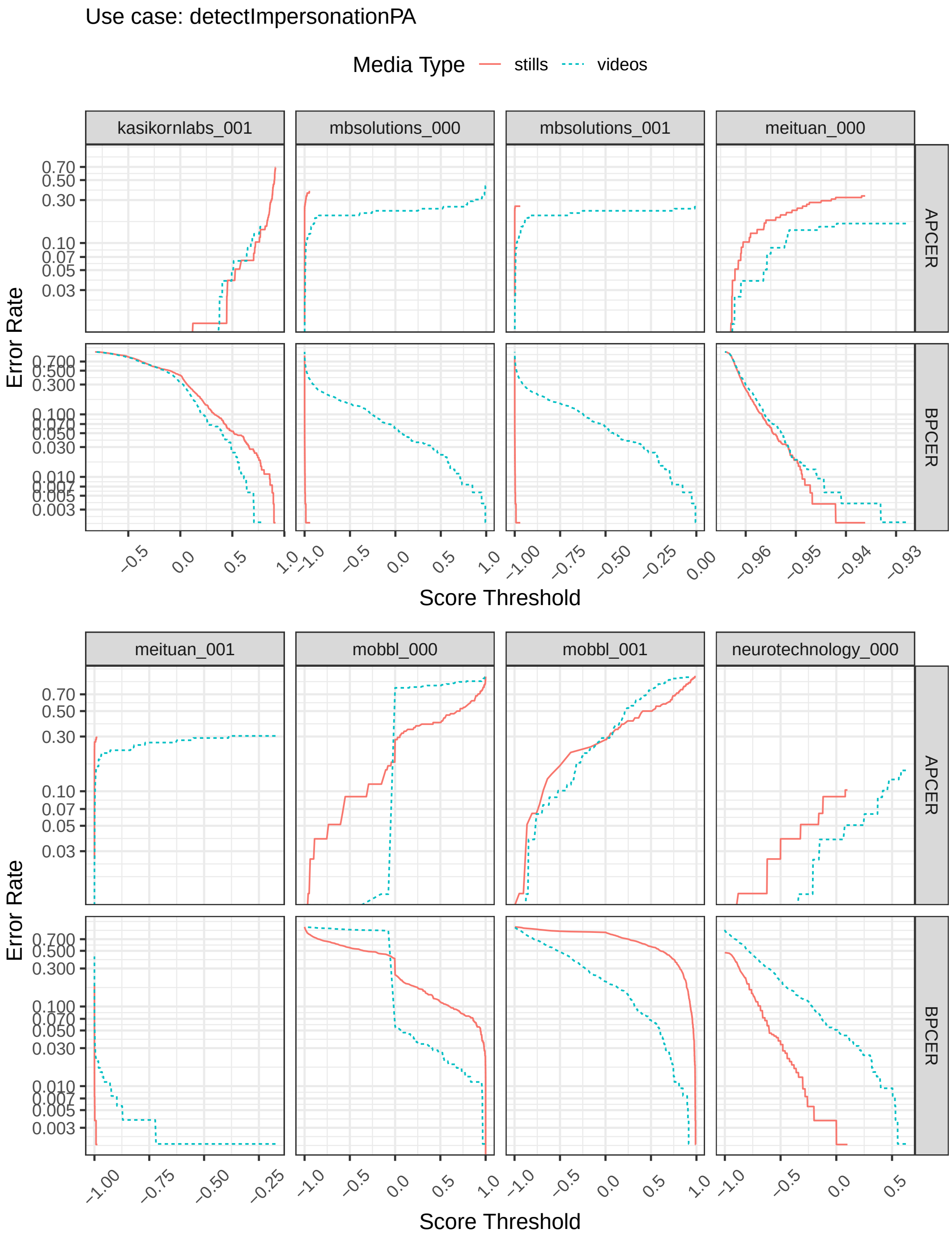


**Fig. 52.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

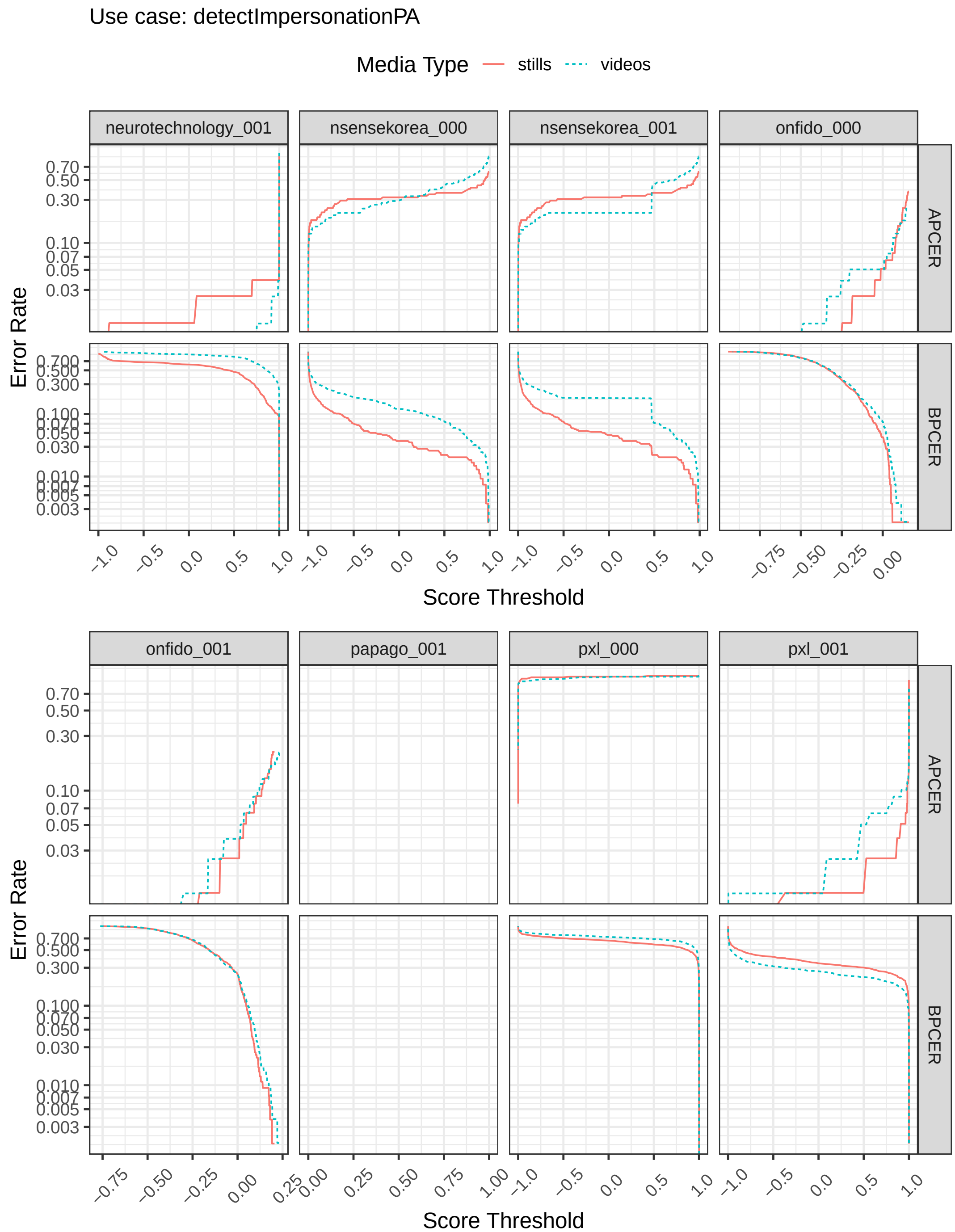


**Fig. 53.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

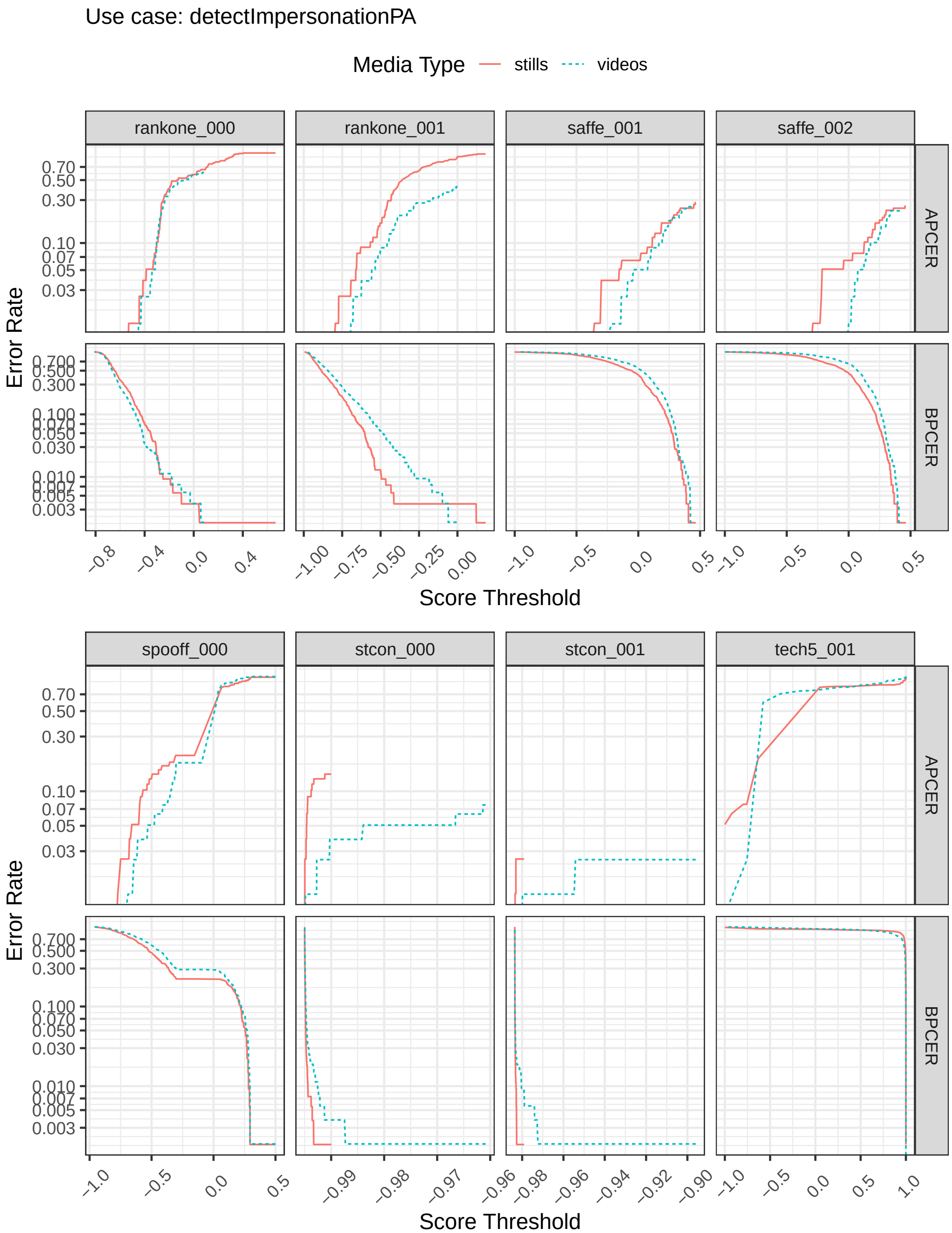


**Fig. 54.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

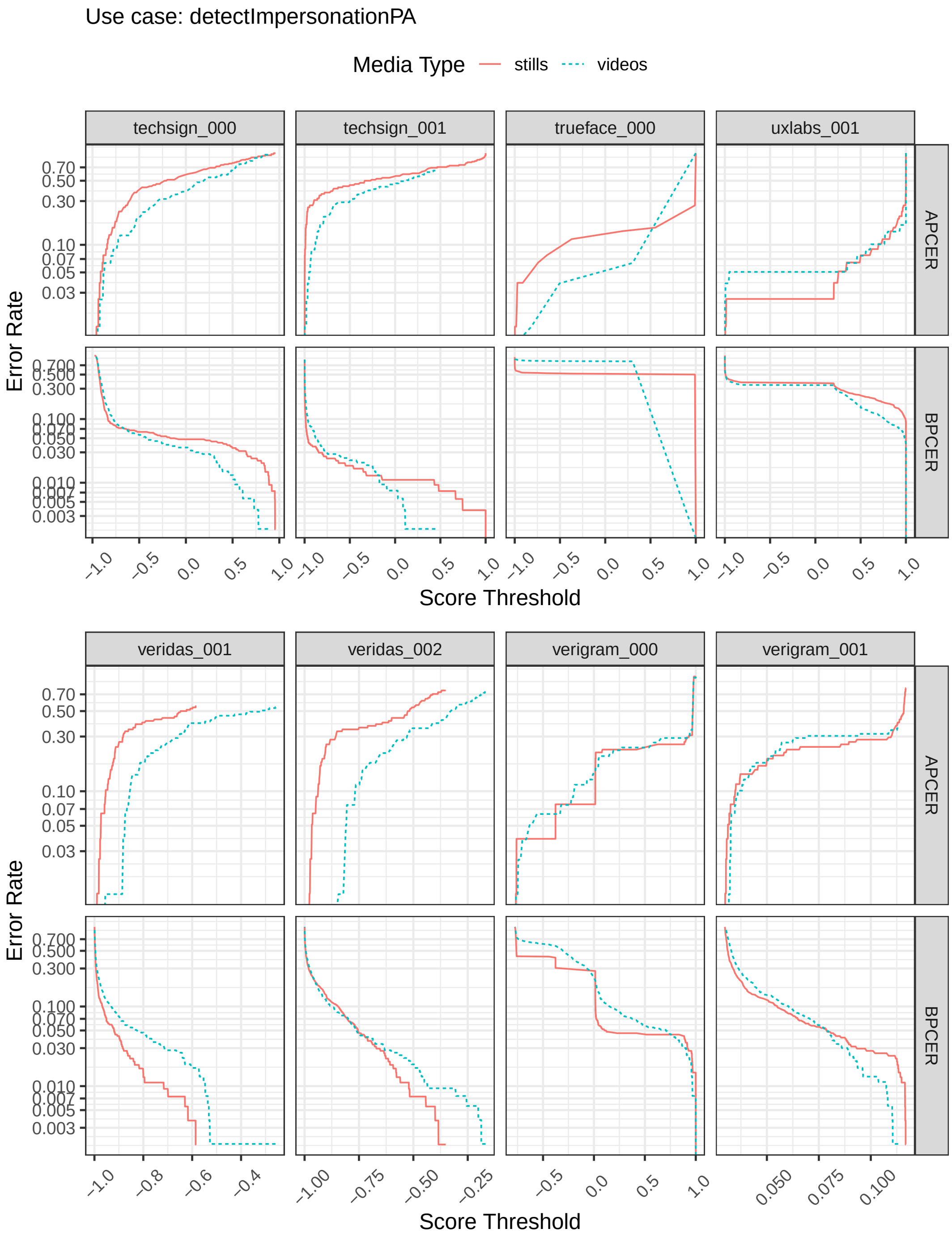


**Fig. 55.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

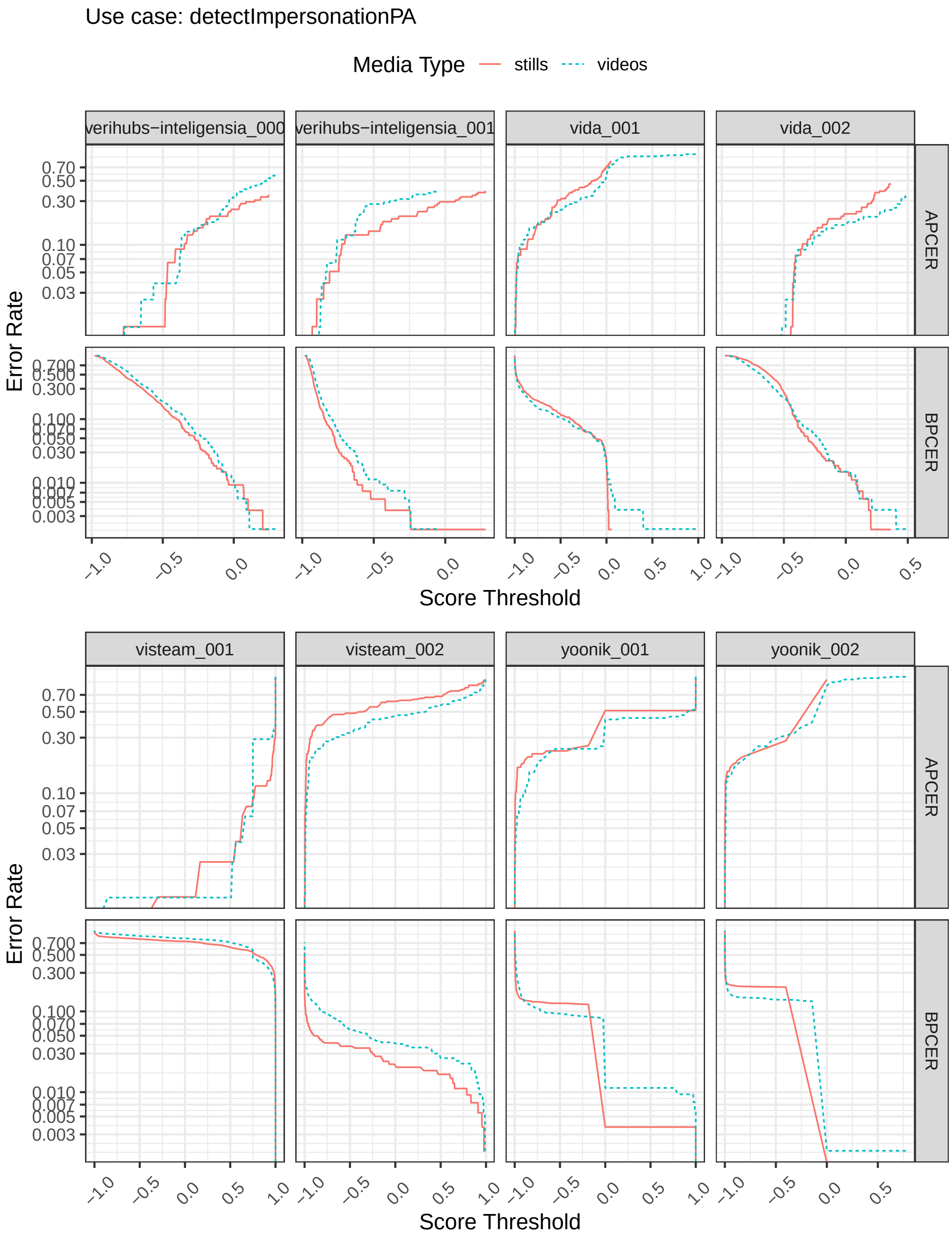
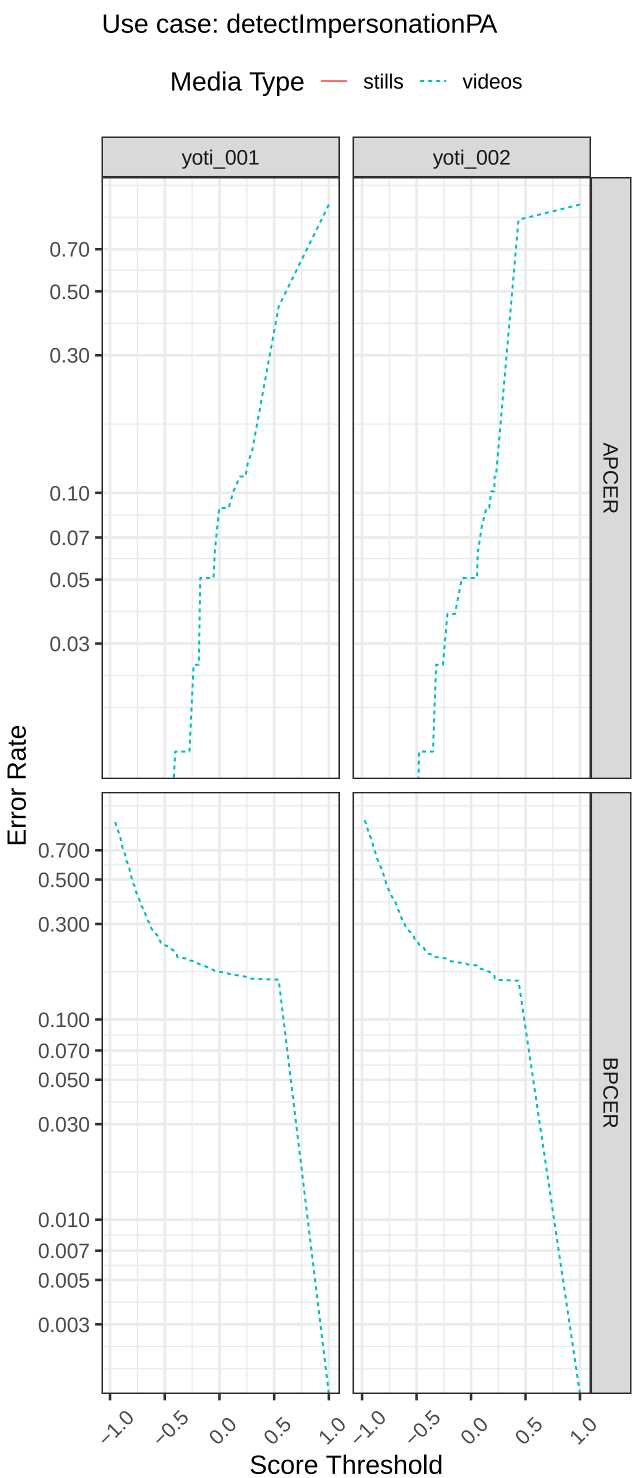


**Fig. 56.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.



## Appendix B.2. Evasion

**Table 55.** Use Case: detectEvasionPA - Stills vs. Videos

| | (Convenience) APCER @ BPCER=0.01 | | | (Security) BPCER @ APCER=0.01 | |
|---|---|---|---|---|---|
| Algorithm | Stills | Videos | Algorithm | Stills | Videos |
| alchera-000 | 1.00 | 1.00 | alchera-000 | 1.00 | 1.00 |
| alice-000 | 0.49 | 1.00 | alice-000 | 0.49 | 0.62 |
| aware-001 | 0.52 | 0.82 | aware-001 | 0.49 | 0.57 |
| aware-002 | 0.68 | 0.81 | aware-002 | 0.51 | 0.72 |
| cubox-000 | 0.96 | 0.95 | cubox-000 | 0.98 | 0.95 |
| cubox-001 | 0.95 | 0.93 | cubox-001 | 0.99 | 0.97 |
| cyberlink-001 | 0.92 | 0.86 | cyberlink-001 | 0.85 | 0.84 |
| cyberlink-002 | 0.75 | 0.52 | cyberlink-002 | 0.24 | 0.28 |
| facedirect-001 | 0.80 | 0.88 | facedirect-001 | 0.98 | 0.92 |
| facedirect-002 | 0.83 | 0.72 | facedirect-002 | 1.00 | 1.00 |
| griaule-000 | 0.90 | 0.89 | griaule-000 | 0.99 | 1.00 |
| griaule-001 | 0.91 | 0.90 | griaule-001 | 0.95 | 0.98 |
| jcv-001 | 1.00 | 1.00 | jcv-001 | 0.99 | 1.00 |
| kakao-000 | 0.25 | 0.19 | kakao-000 | 0.16 | 0.17 |
| kakao-001 | 0.11 | 0.04 | kakao-001 | 0.11 | 0.03 |
| kasikornlabs-000 | 0.38 | 0.32 | kasikornlabs-000 | 0.84 | 0.90 |
| kasikornlabs-001 | 0.47 | 0.36 | kasikornlabs-001 | 0.84 | 0.88 |
| neurotechnology-000 | 0.37 | 0.44 | neurotechnology-000 | 1.00 | 0.57 |
| neurotechnology-001 | 1.00 | 1.00 | neurotechnology-001 | 0.82 | 0.89 |
| onfido-000 | 0.36 | 0.38 | onfido-000 | 0.74 | 0.81 |
| onfido-001 | 0.53 | 0.49 | onfido-001 | 0.77 | 0.71 |
| papago-001 | 1.00 | 1.00 | papago-001 | 1.00 | 1.00 |
| rankone-000 | 0.75 | 0.89 | rankone-000 | 0.92 | 0.92 |
| rankone-001 | 0.75 | 0.89 | rankone-001 | 0.92 | 0.92 |
| spooff-000 | 1.00 | 1.00 | spooff-000 | 1.00 | 1.00 |
| trueface-000 | 0.97 | 0.96 | trueface-000 | 1.00 | 1.00 |
| uxlabs-001 | 1.00 | 1.00 | uxlabs-001 | 0.48 | 0.51 |

**Fig. 57.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

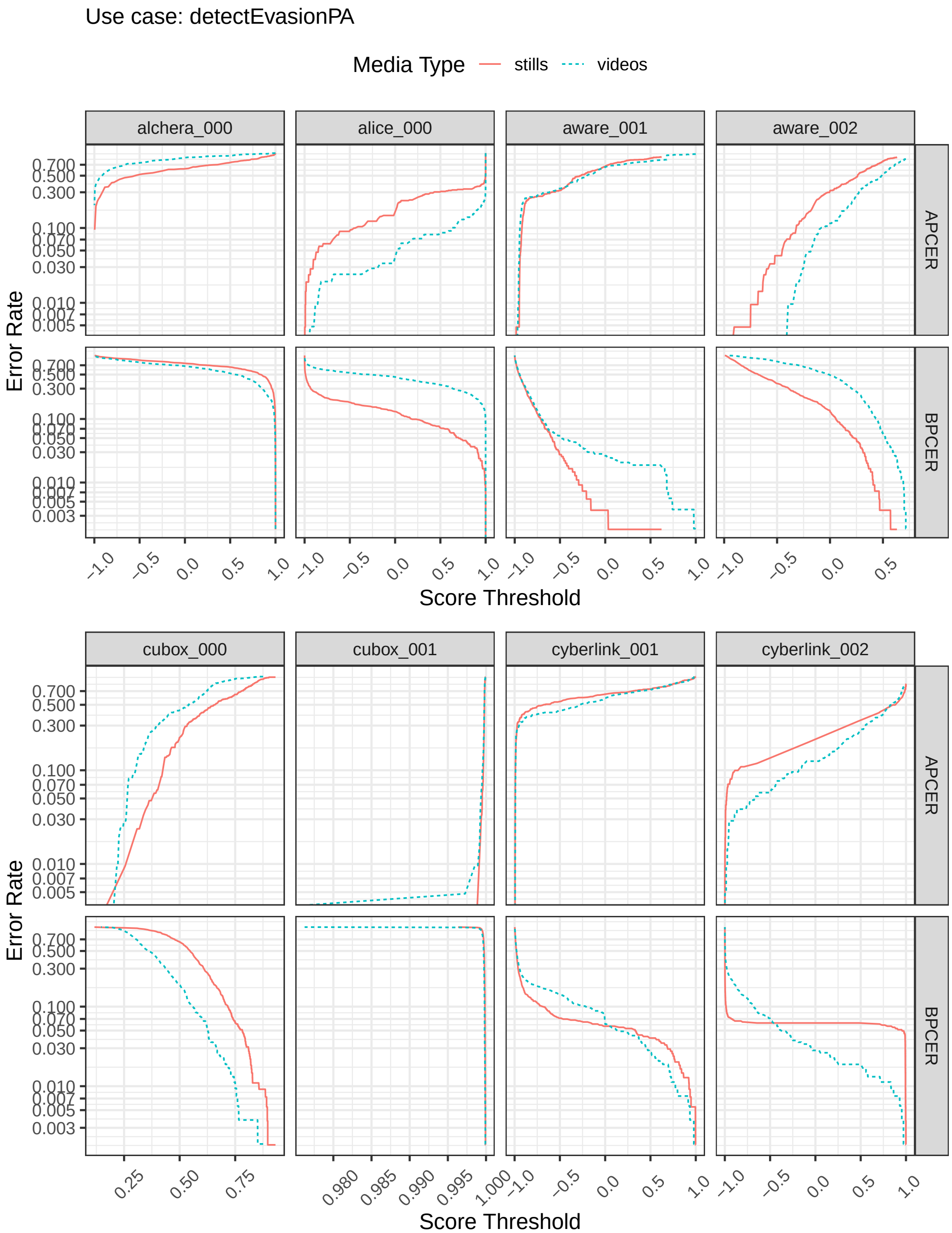


**Fig. 58.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

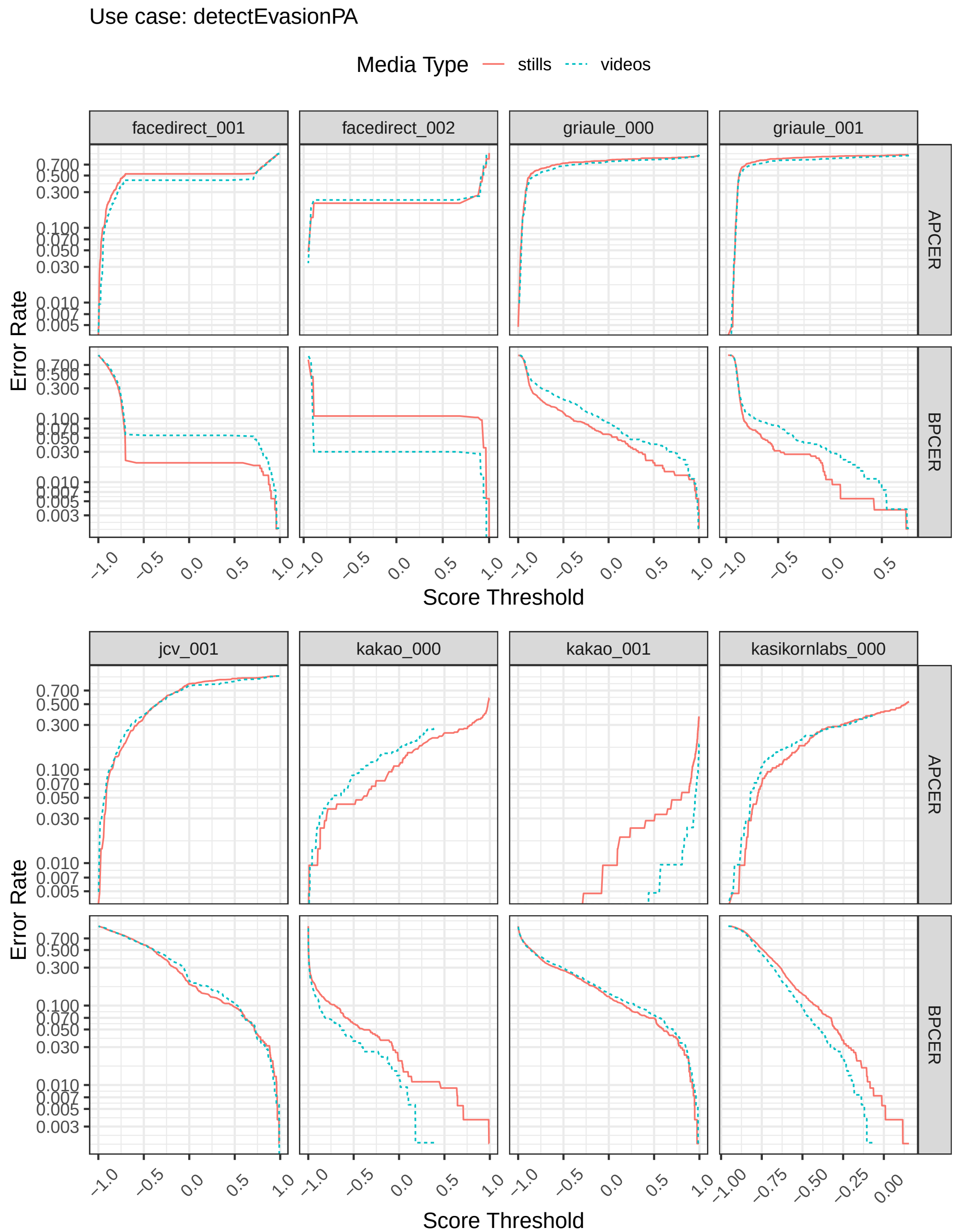


**Fig. 59.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.

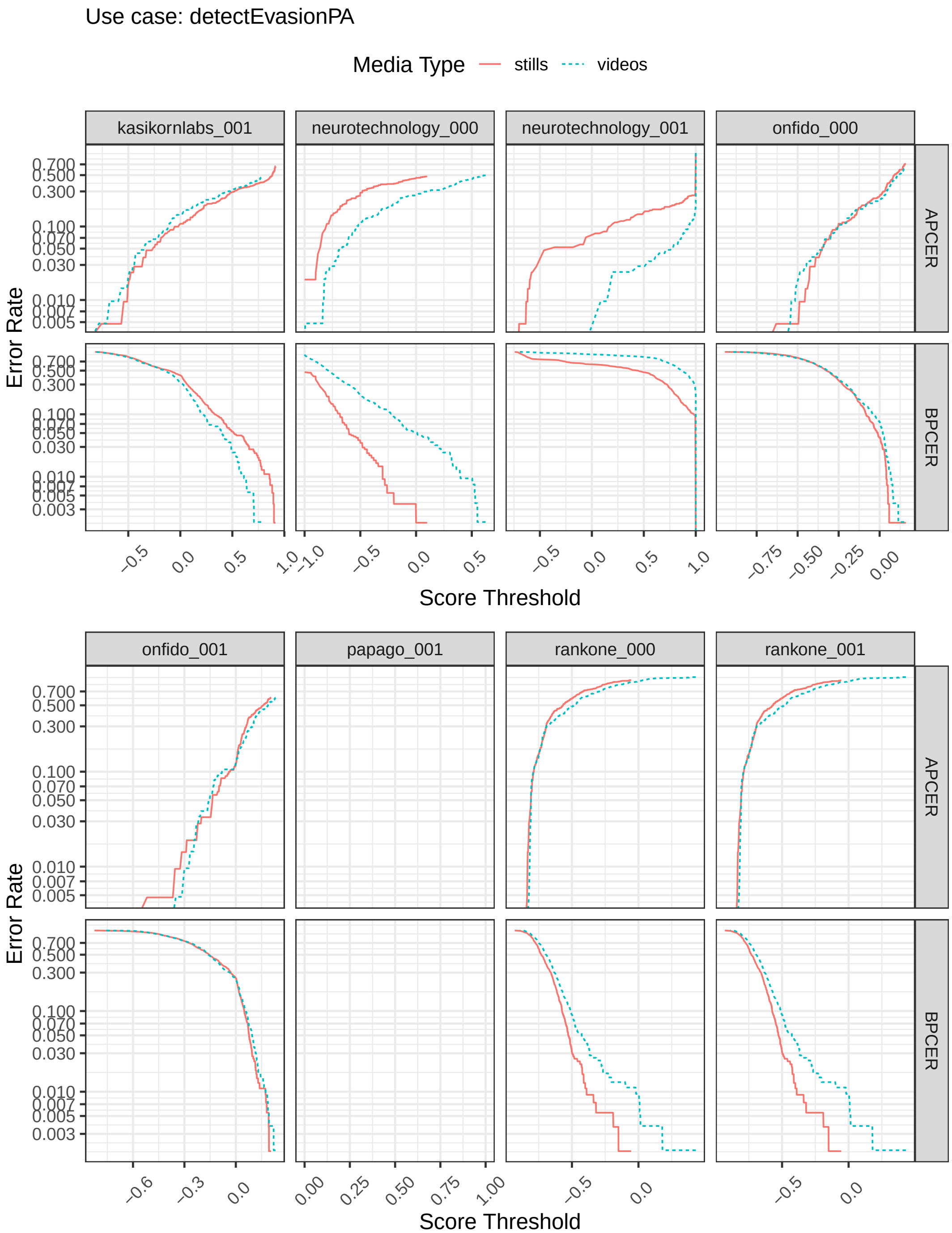
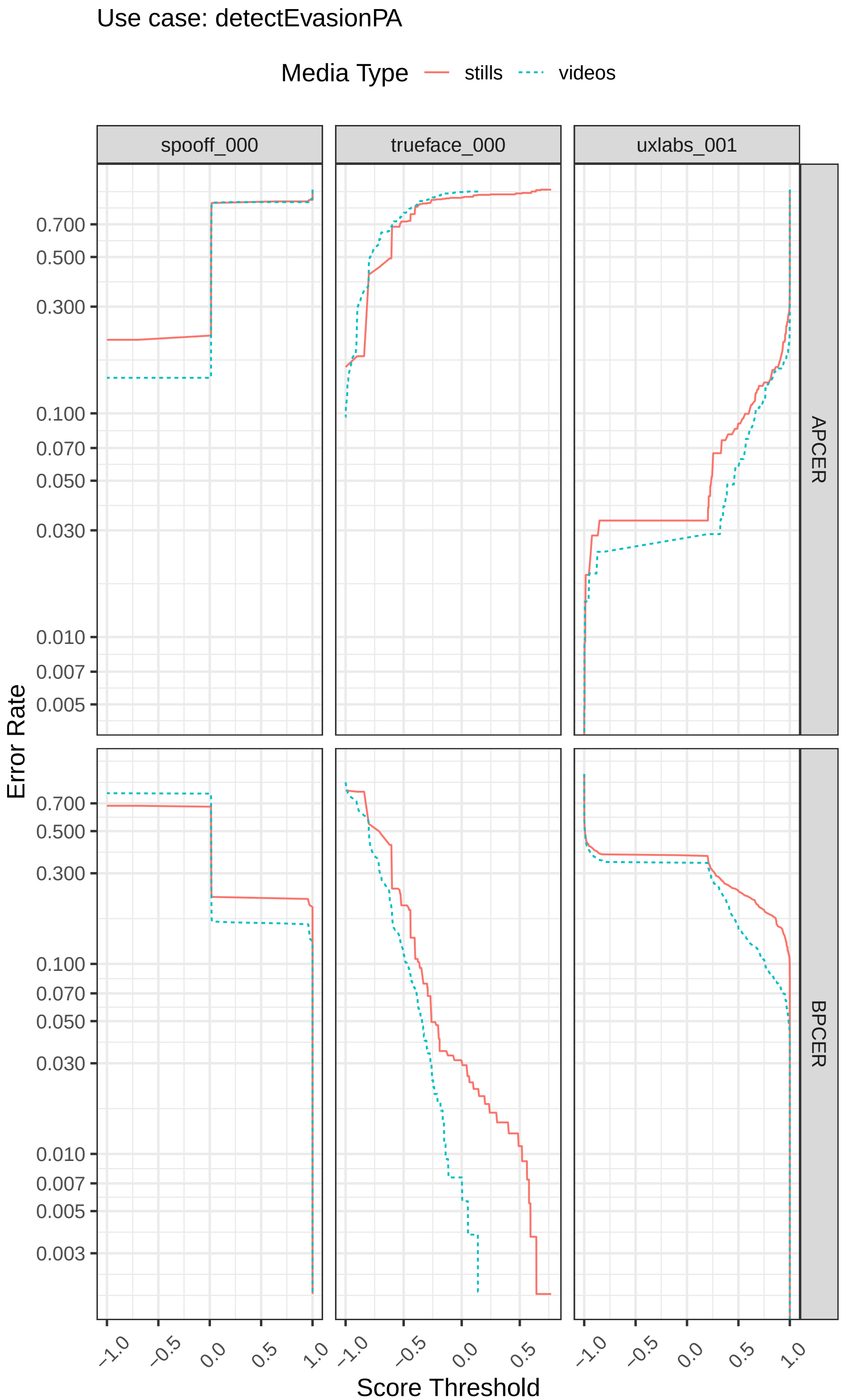


**Fig. 60.** This plot presents APCER and BPCER as a function of threshold on still images vs. videos.



## Appendix C. Demographic Effects

### Appendix C.1. Impersonation

**Fig. 61.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

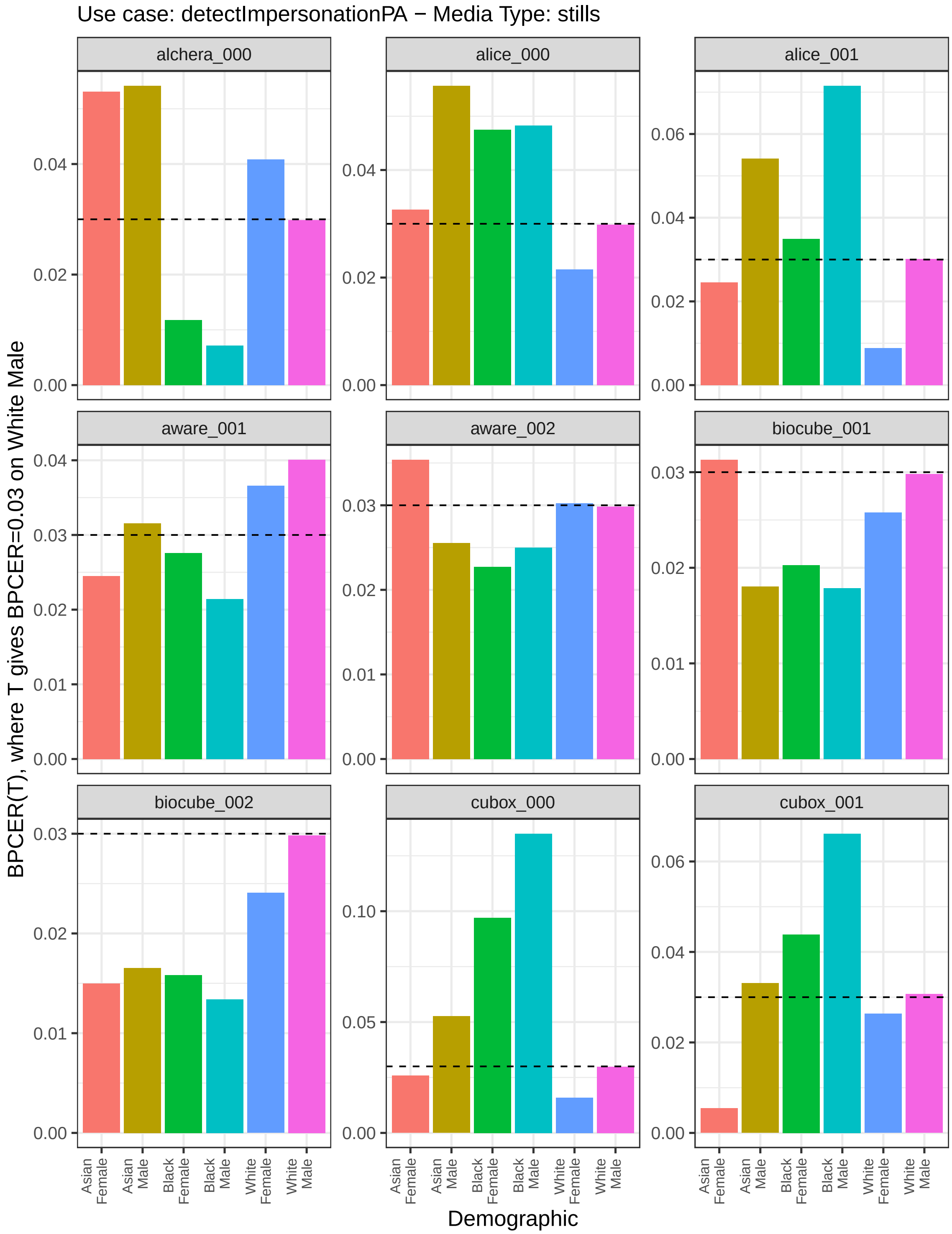


**Fig. 62.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

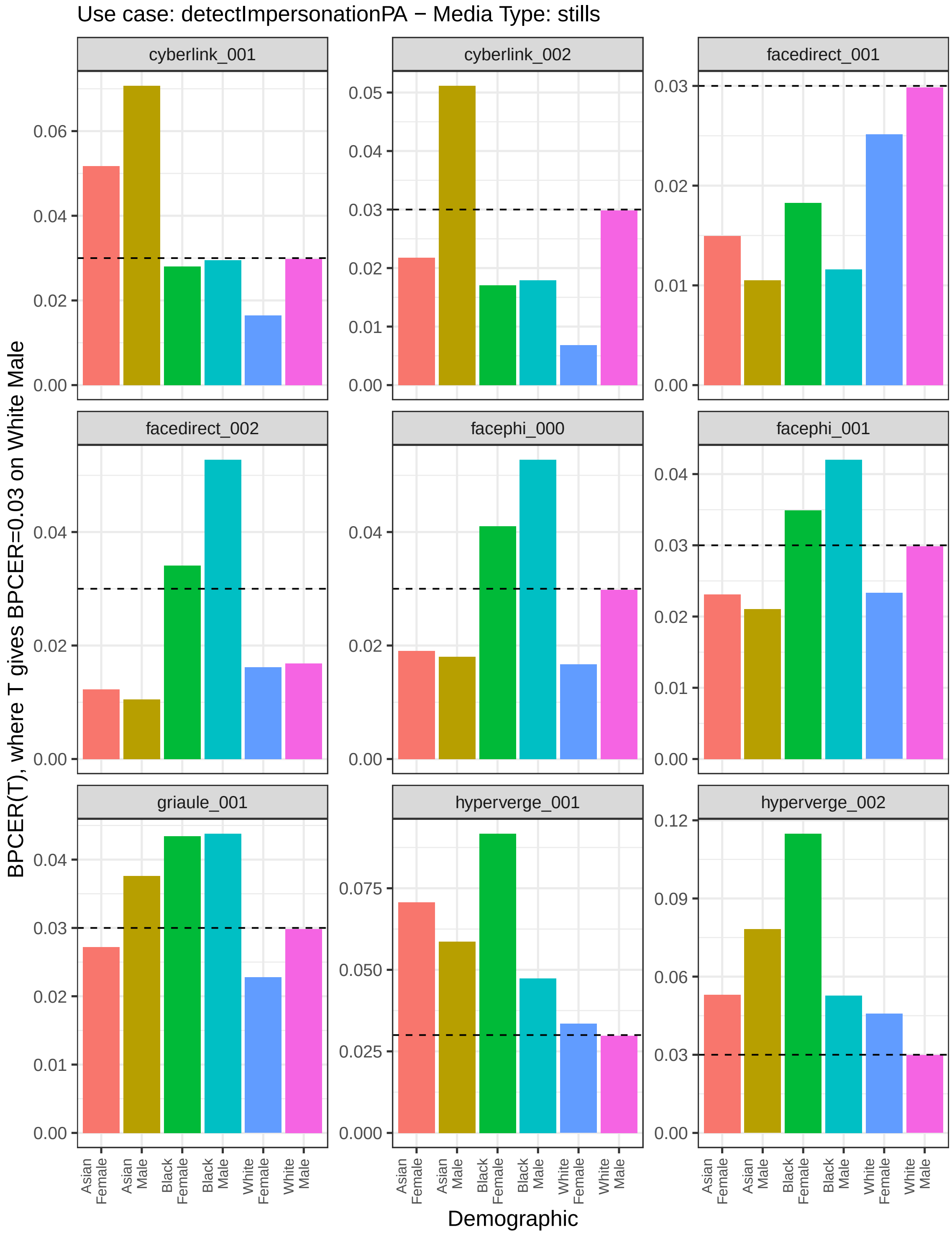


**Fig. 63.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

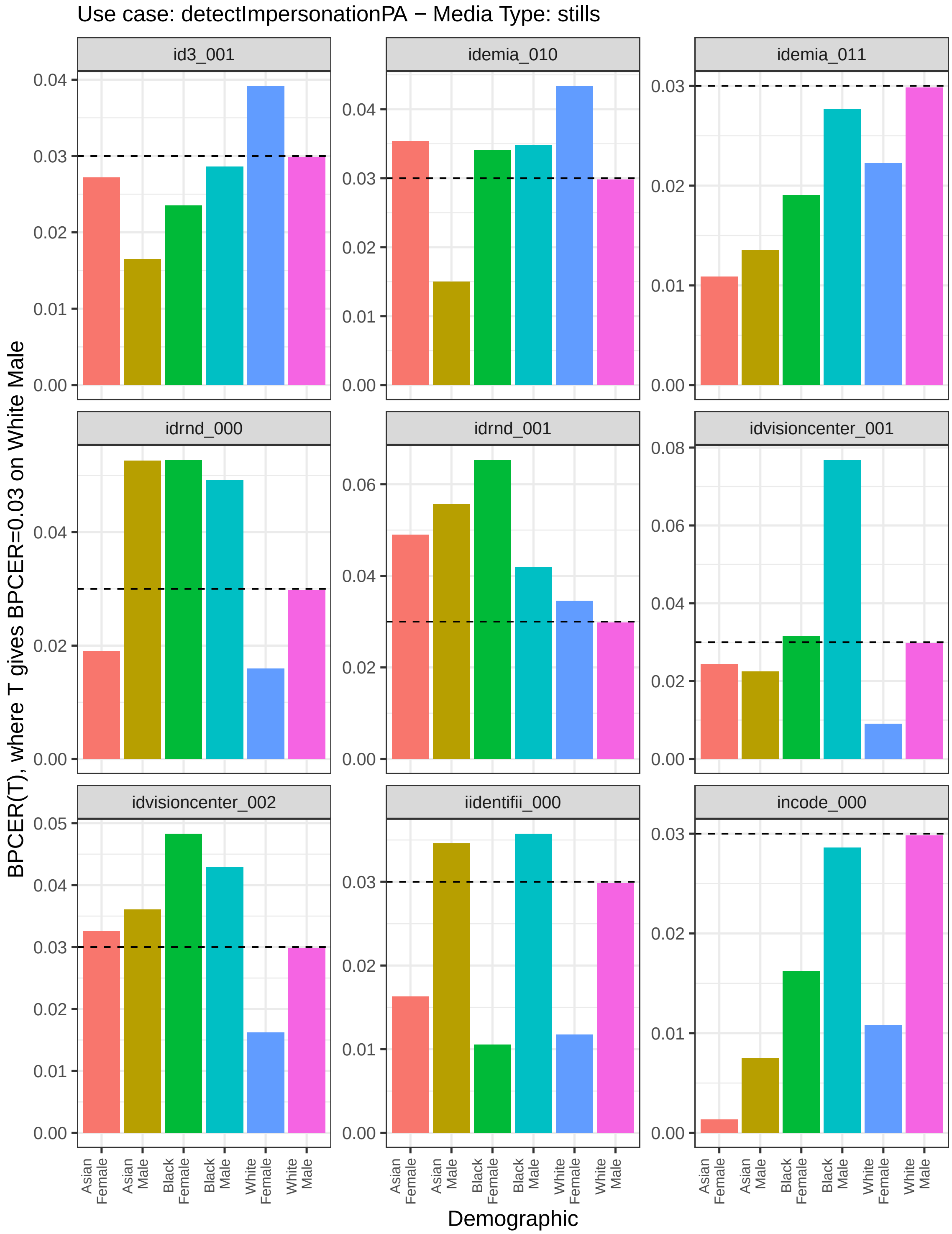


**Fig. 64.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

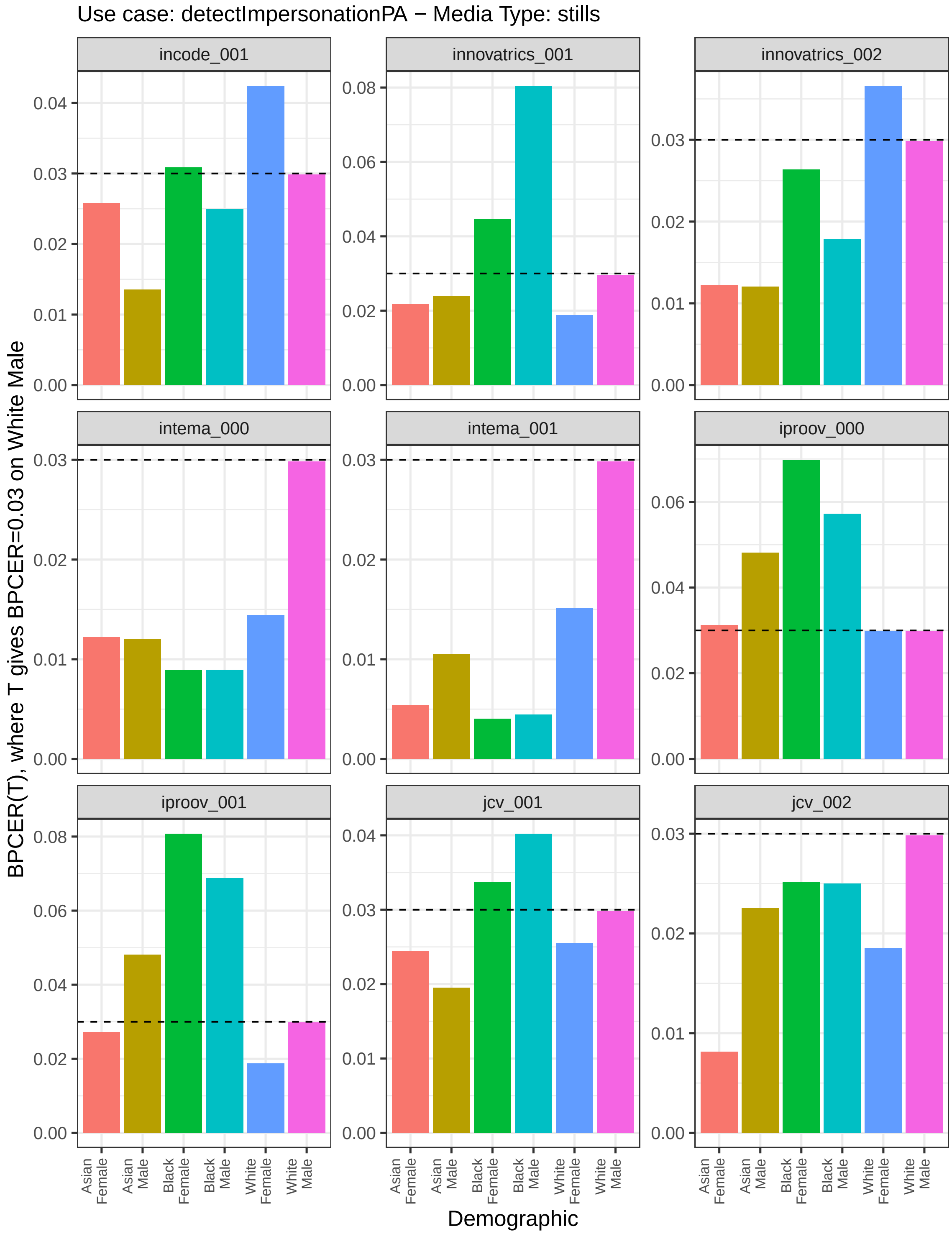


**Fig. 65.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

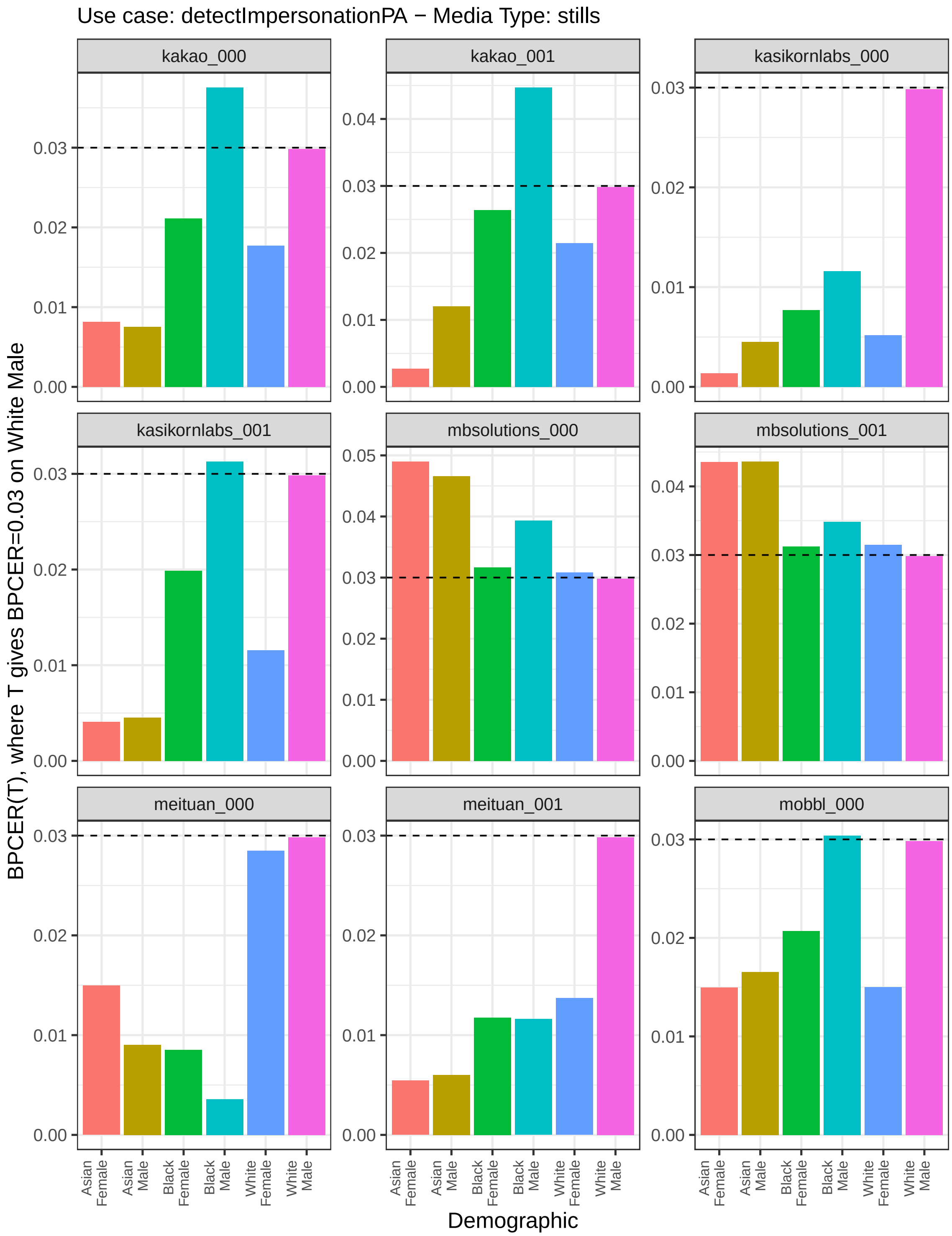


**Fig. 66.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

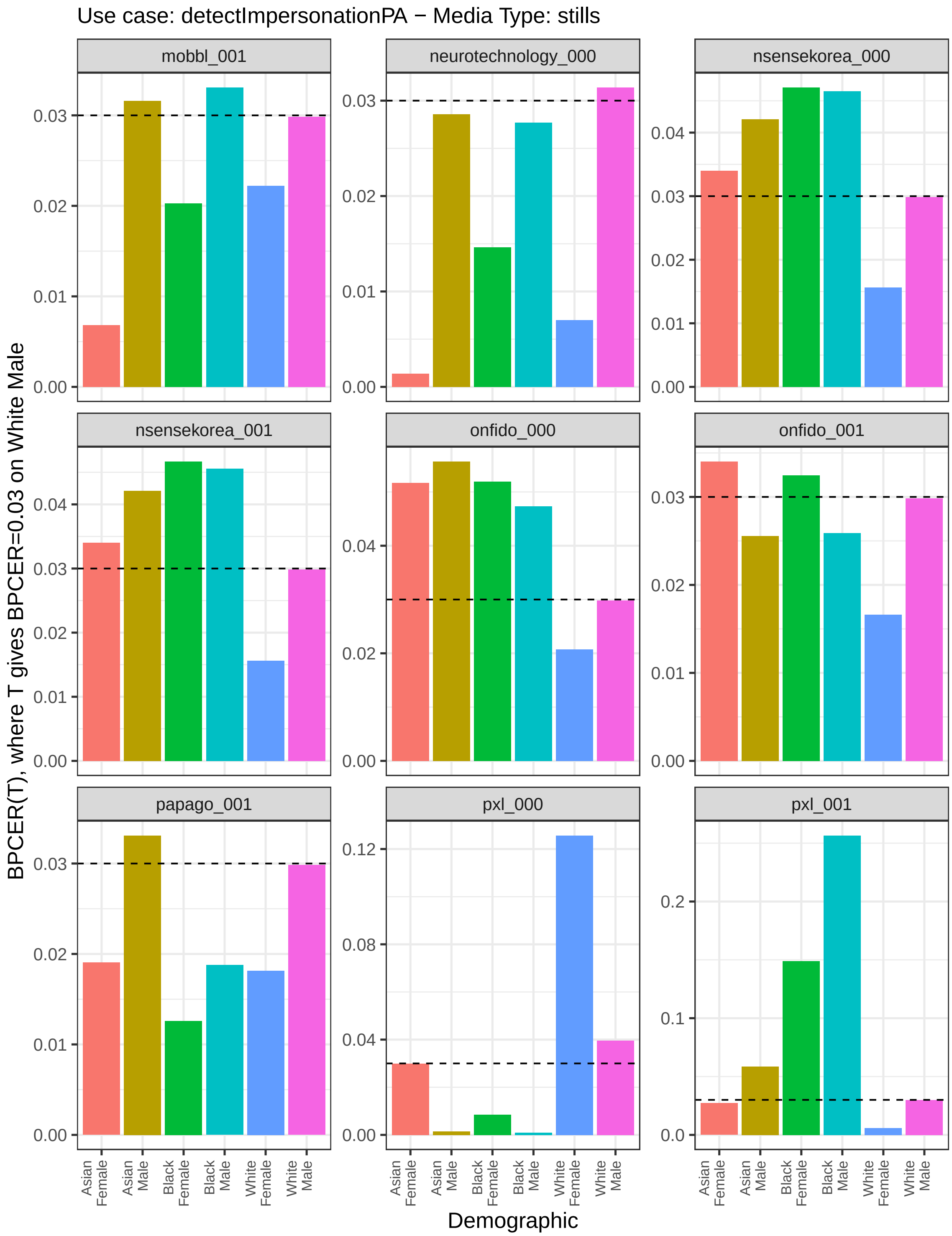


**Fig. 67.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

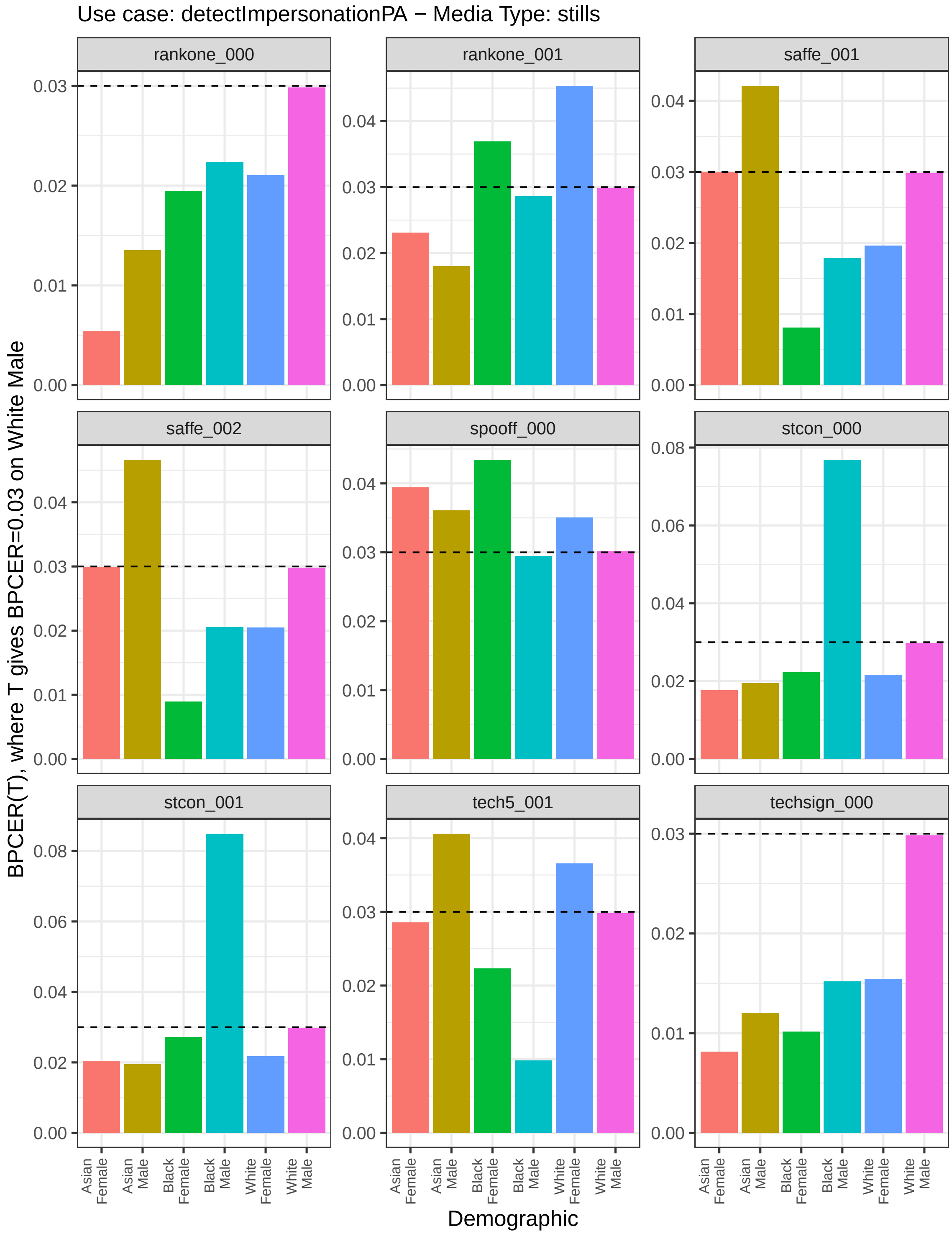


**Fig. 68.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

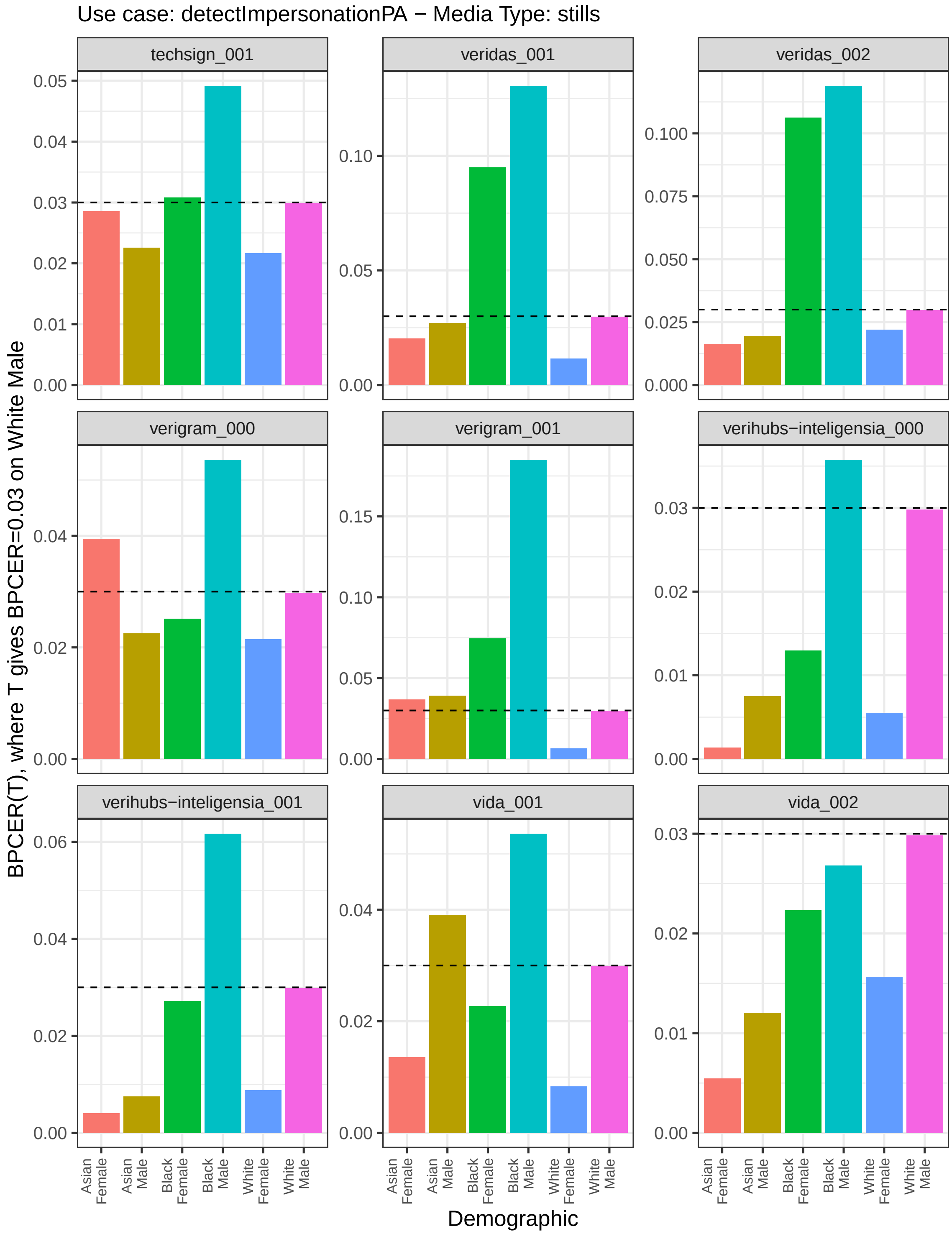
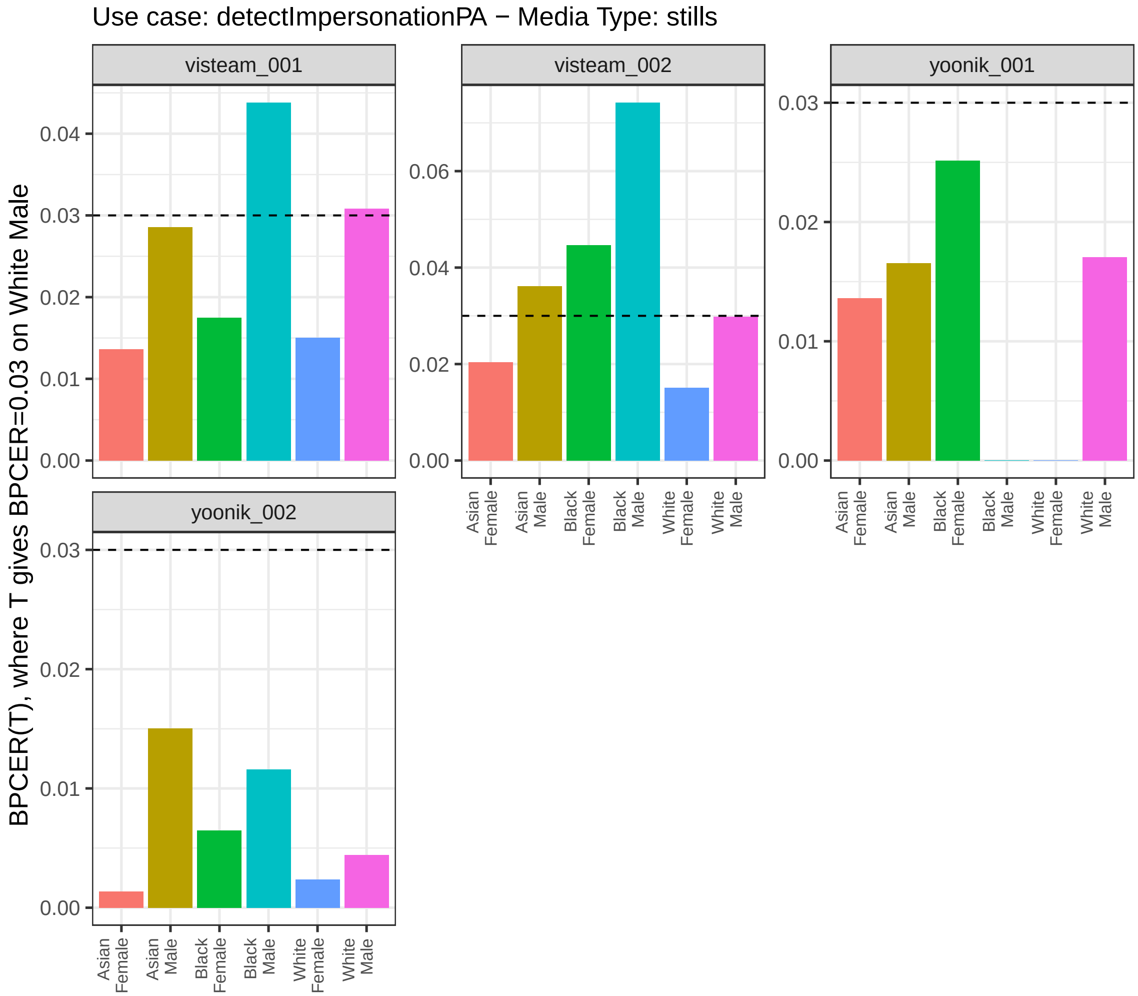


**Fig. 69.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.



## Appendix C.2. Evasion

**Fig. 70.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

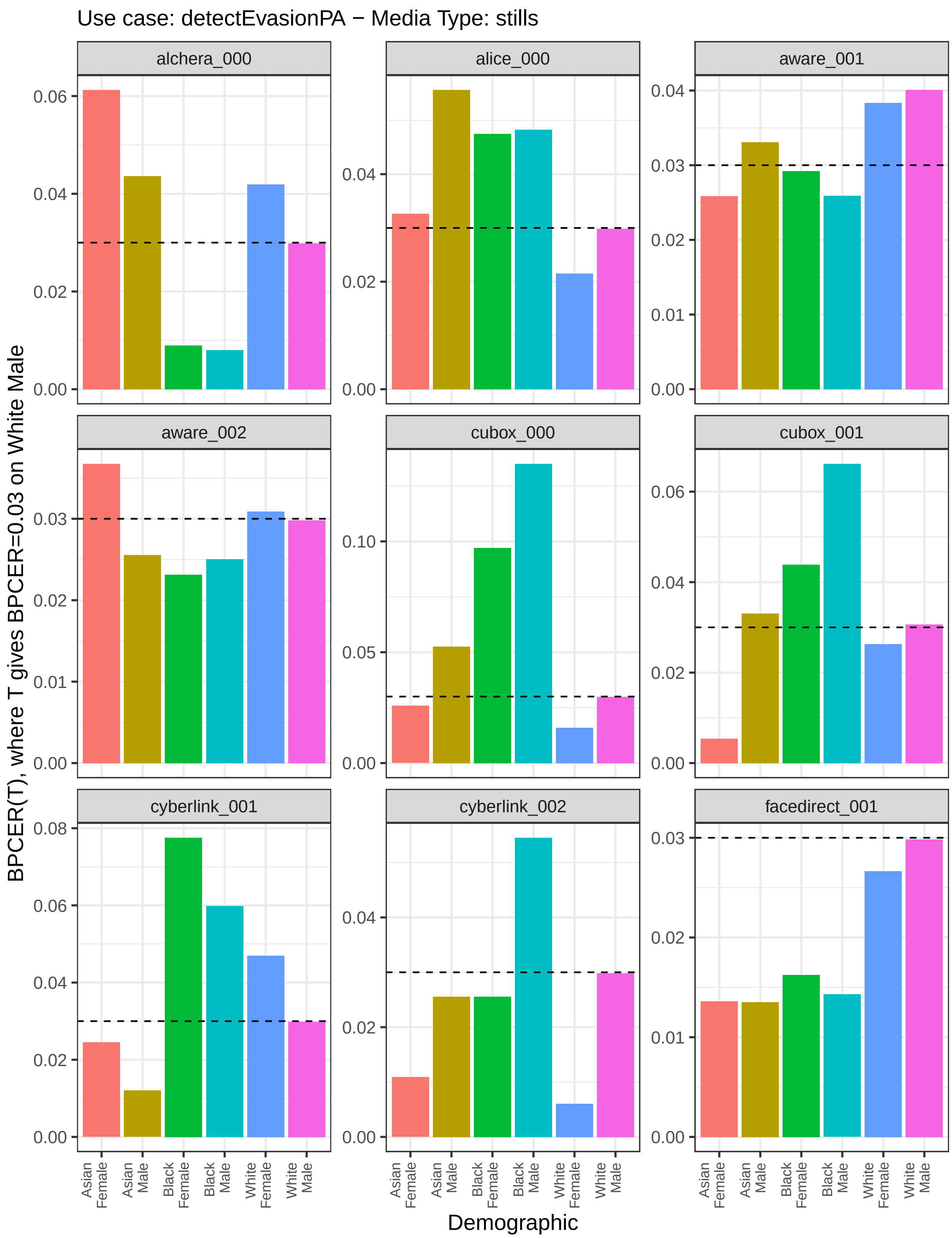


**Fig. 71.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.

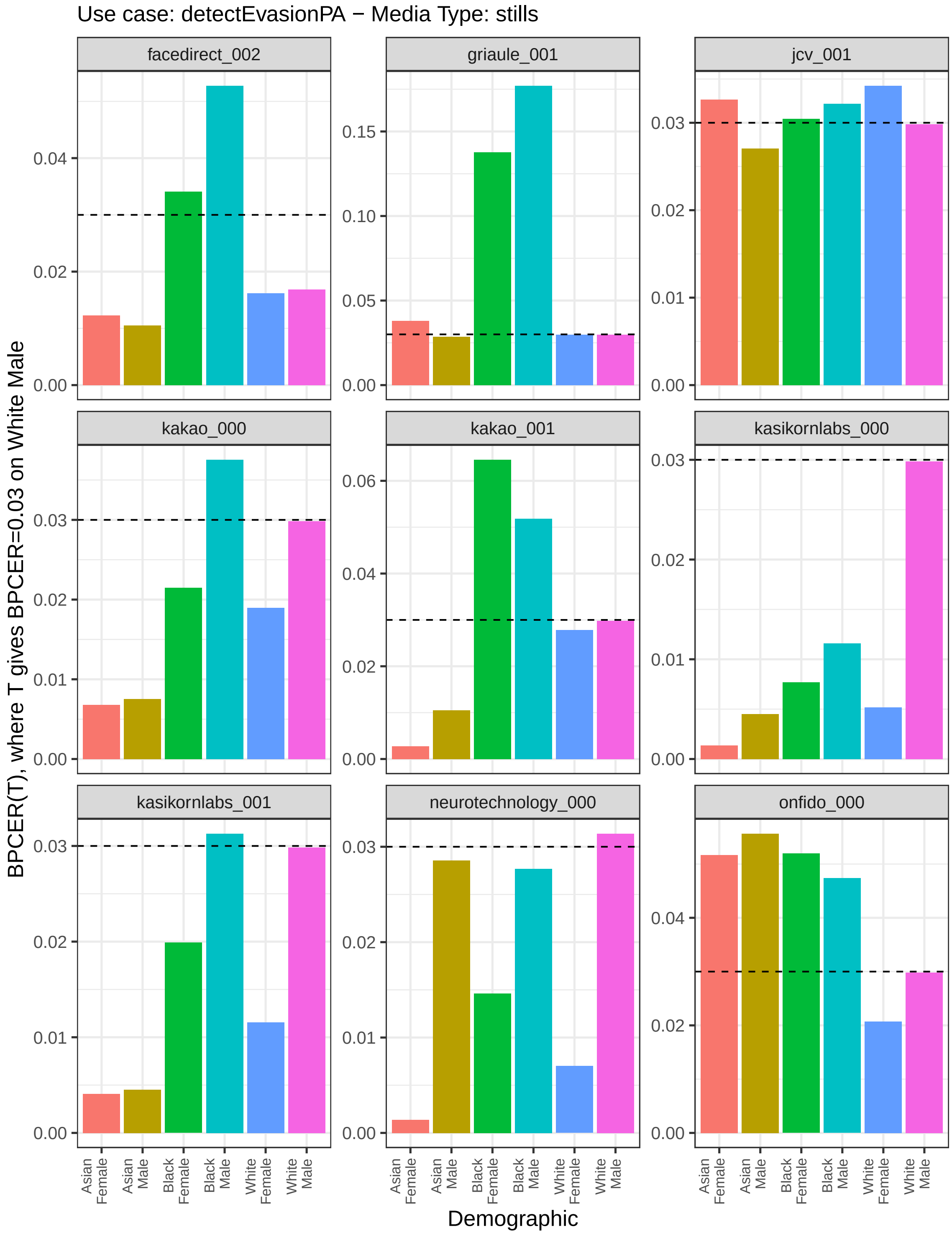
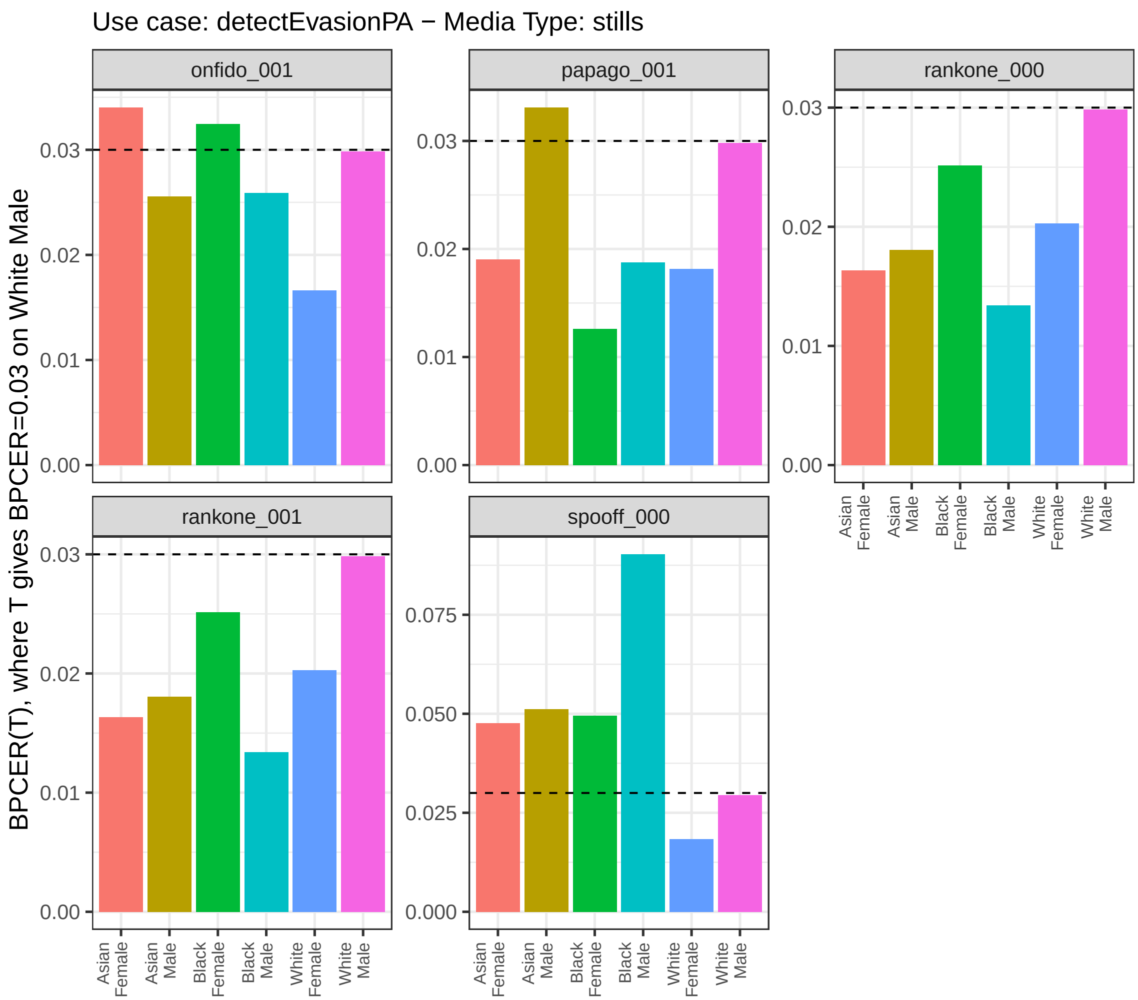


**Fig. 72.** The plot presents BPCER/false detection rate for different race-sex groups at a fixed threshold that gives BPCER equal (or closest) to 0.03 on White Male. Algorithms where BPCER of 0.03 is not attainable are not plotted.



## Appendix D. Abbreviations

**PA** Presentation Attack.

**PAI** Presentation Attack Instrument.

**PAD** Presentation Attack Detection.

**APCER** Attack Presentation Classification Error Rate.

**BPCER** Bona Fide Classification Error Rate.

**APNRR** Attack Presentation Non-Response Rate.

**BPNRR** Bona Fide Presentation Non-Response Rate.