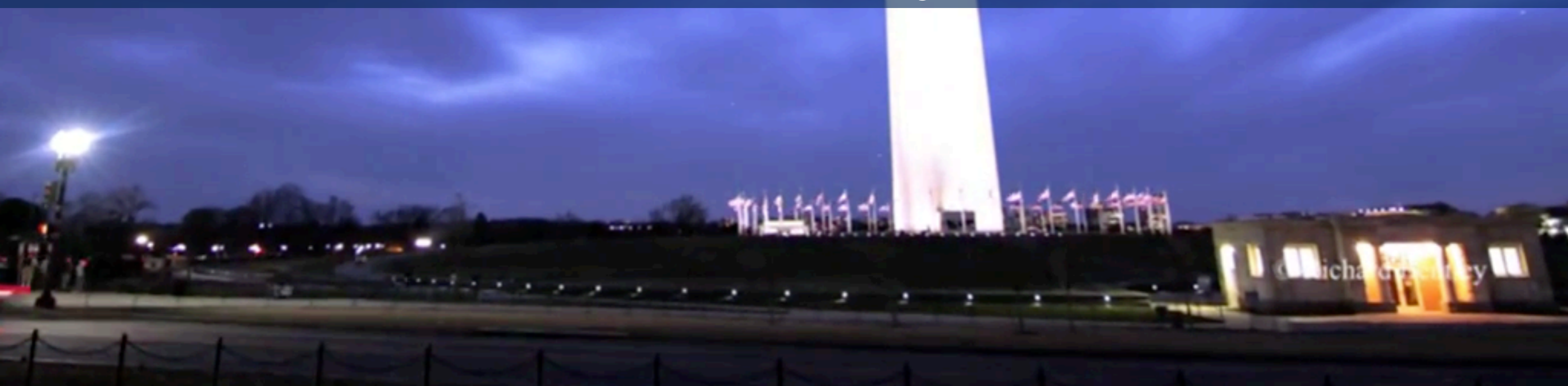


Diffusion of Voter Responsibility:

Potential Failings in E2E Receipt Checking

Ester Moher, Jeremy Clark, & Aleks Essex



Consider any simple mechanism that enables a user to detect a potential security threat

e.g., alarm, webcam light, a ballot receipt number

Consider any simple mechanism that enables a user to detect a potential security threat

e.g., alarm, webcam light, a ballot receipt number

Detecting the *mechanism* is not the same as detecting the *threat*





Somebody's Watching Me?

Assessing the Effectiveness of Webcam Indicator Lights

Rebecca S. Portnoff¹, Linda N. Lee¹,
Serge Egelman^{1,2}, Pratyush Mishra¹, Derek Leung¹, and David Wagner¹

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²International Computer Science Institute, Berkeley, CA, egelman@icsi.berkeley.edu

ABSTRACT

Most laptops and personal computers have webcams with LED indicators to notify users when they are recording. Because hackers use surreptitiously captured webcam recordings to extort users, we explored the effectiveness of these indicators under varying circumstances and how they could be improved. We observed that, on average, fewer than half of our participants (45%) noticed the existing indicator during computer-based tasks. When seated in front of the computer performing a paper-based task, only 5% noticed the indicator. We performed a followup experiment to evaluate a new indicator and observed that adding onscreen glyphs had a significant impact on both computer-based and non-computer-based tasks (93% and 59% noticed the new indicator, respectively). We discuss how our results can be integrated into current systems, as well as future ubiquitous computing systems.

Author Keywords

Privacy Indicators; Ubiquitous Computing; Usable Security

ACM Classification Keywords

K.6.5. Management of Computing and Information Systems: Security and protection; H.5.2. Information Interfaces and

space of these privacy indicators, we examined the effectiveness of similar privacy indicators that are already sufficiently pervasive: webcam recording indicators.

For several years now, laptop sales have surpassed desktop sales [21], and with few exceptions, it is standard for a new laptop to come equipped with a built-in webcam. These webcams face the user and have indicator LEDs to communicate when the webcam is recording. Ideally, the user will notice the indicator, understand that a recording is being made, and take defensive actions in the event that the webcam is recording without the user's consent. Anecdotal evidence suggests that these assumptions are incorrect [13].

Remote Administration Tools (RATs) allow hackers to control an unsuspecting user's computer remotely, allowing them to execute programs, send taunting messages, or eavesdrop via the webcam and microphone [4]. In some cases, hackers have used videos of victims in various states of undress as part of "sextortion" plots: the perpetrator threatens to publicly post the captured videos and/or photos unless the victim pays a ransom [3]. The most famous case of this involved a high school classmate of Miss Teen USA who surreptitiously captured photos of her naked in her bedroom [19]. Unauthorized

Somebody's Watching Me?

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Nineteen participants reported that their webcam LED turned on when they were not using it. Almost all of them (18 of 19) believed this was normal behavior or just due to human error...

Author Keywords

Privacy Indicators; Ubiquitous Computing; Usable Security

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... suggests that the existing indicator is not effective. We suggest a new design for the indicator that is more effective. We also discuss the implications of our findings for the design of privacy indicators in general. We conclude with a discussion of the implications of our findings for the design of privacy indicators in general.

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City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

OFFICIAL BALLOT — WARD 3

Instructions: Vote for candidates by indicating your first-choice candidate, your second-choice candidate, and so on. You are free to rank only a first choice if you wish.

Do not fill in more than one oval per column. Do not fill in more than one oval per candidate. Do not skip numbers in the ranking sequence.

To vote for a person whose name is not printed on the ballot, write the name in the space provided and fill in one box in the column indicating your ranking of the write-in candidate.

If you make a mistake on your ballot, return it to the judge and get another.

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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

Instrucciones: Vote por los candidatos indicando el candidato que sea su primera opción, el candidato que sea su segunda opción, y así sucesivamente. Si lo desea, puede limitarse a seleccionar solamente al candidato que sea su primera opción.

No rellene más de una casilla por cada columna. No rellene más de una casilla por cada candidato. No salte números en la secuencia de clasificación por orden.

Para votar por una persona cuyo nombre no está impreso en la boleta, escriba el nombre en el espacio provisto y rellene una casilla en la columna para indicar el orden de clasificación del candidato que se le añadió.

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No haga marcas en su boleta que puedan identificarlo.

Cuando usted marque la casilla para votar por un candidato, verá un código que podrá usar posteriormente para verificar su voto por Internet. Vea la hoja de instrucciones en la cabina de votación.

| MAYOR ALCALDE | | | |
|--|----------------------------------|----------------------------------|----------------------------------|
| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción | 3rd choice 3ra opción |
| Roger B. Schlegel | <input checked="" type="radio"/> | <input type="radio"/> | <input type="radio"/> |
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| Tom Smith | <input type="radio"/> | <input checked="" type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| CITY COUNCIL MEMBER WARD 3 MIEMBRO DEL CONSEJO DE LA CIUDAD DISTRITO ELECTORAL 3 | | |
|--|--------------------------|--------------------------|
| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción |
| Dan Robinson | <input type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> |



3-972853

Online Verification Number
Número de Verificación por Internet

City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
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BOLETA OFICIAL — DISTRITO ELECTORAL 3

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3-972853

Online Verification Number
Número de Verificación por Internet

Confirmation Code
(056)

Ballot ID
(3-972853)

City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

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Confirmation Code
(056)

Ballot ID
(3-972853)

Type in your Ballot ID: _____



3-972853
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City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

OFFICIAL BALLOT — WARD 3

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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

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Confirmation Code
(056)

Ballot ID
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Type in your Ballot ID: 3972853



3-972853
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City of Takoma Park, Maryland
MUNICIPAL ELECTION
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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

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| CITY COUNCIL MEMBER WARD 3 MIEMBRO DEL CONSEJO DE LA CIUDAD DISTRITO ELECTORAL 3 | | |
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| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción |
| Dan Robinson | <input type="radio"/> | <input type="radio"/> |

Confirmation Code
(056)

Ballot ID
(3-972853)

Type in your Ballot ID: 3972853

Thank you. Your confirmation code is 856

Scantegrity II Municipal Election at Takoma Park: The First E2E Binding Governmental Election with Ballot Privacy

Richard Carback
UMBC CDL

David Chaum

Jeremy Clark
University of Waterloo

John Conway
UMBC CDL

Aleksander Essex
University of Waterloo

Paul S. Herrnson
UMCP CAPC

Travis Mayberry
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Stefan Popoveniuc

Ronald L. Rivest
MIT CSAIL

Emily Shen
MIT CSAIL

Alan T. Sherman
UMBC CDL

Poorvi L. Vora
GW

Abstract

On November 3, 2009, voters in Takoma Park, Maryland, cast ballots for the mayor and city council members using the Scantegrity II voting system—the first time any *end-to-end (E2E)* voting system with ballot privacy has been used in a binding governmental election. This case study describes the various efforts that went into the election—including the improved design and implementation of the voting system, streamlined procedures, agreements with the city, and assessments of the experiences of voters and poll workers.

The election, with 1728 voters from six wards, involved paper ballots with invisible-ink confirmation codes, instant-runoff voting with write-ins, early and absentee (mail-in) voting, dual-language ballots, provisional ballots, privacy sleeves, any-which-way scanning with parallel conventional desktop scanners, end-to-end

learned. While the paper provides a simple summary of survey results, the focus of this paper is not usability but the engineering process of bringing a new cryptographic approach to solve a complex practical problem involving technology, procedures, and laws.

With the Scantegrity II voting system, voters mark optical scan paper ballots with pens, filling the oval for the candidates of their choice. These ballots are handled as traditional ballots, permitting all the usual automated and manual counting, accounting, and recounting. Additionally, the voting system provides a layer of integrity protection through its use of invisible-ink confirmation codes. When voters mark ballot ovals using a decoder pen, confirmation codes printed in invisible ink are revealed. Interested voters can note down these codes to check them later on the election website. The codes are generated randomly for each race and each ballot, and

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Abstract

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Scantegrity received a single complaint by a voter who had trouble deciphering a digit in the code and noted it as “0,” while the Scantegrity website presented it as “8.”

...He also stated that if he were not a trusting individual, he would believe that he had **proof** that his vote was altered.

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City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

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Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

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3-972853

Online Verification Number
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The receipt check is the weakest link in most E2E systems

We wanted to stress test it

City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

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Do not make any identifying marks on your ballot.

When you mark an oval to rank a candidate, a code will be revealed that you may later use to verify your vote online. See the instruction sheet in the voting booth.

Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

Instrucciones: Vote por los candidatos indicando el candidato que sea su primera opción, el candidato que sea su segunda opción, y así sucesivamente. Si lo desea, puede limitarse a seleccionar solamente al candidato que sea su primera opción.

No rellene más de una casilla por cada columna. No rellene más de una casilla por cada candidato. No salte números en la secuencia de clasificación por orden.

Para votar por una persona cuyo nombre no está impreso en la boleta, escriba el nombre en el espacio provisto y rellene una casilla en la columna para indicar el orden de clasificación del candidato que se le añadió.

Si usted comete un error en su boleta, devuélvasela al juez y pida otra.

No haga marcas en su boleta que puedan identificarla.

Cuando usted marque la casilla para votar por un candidato, verá un código que podrá usar posteriormente para verificar su voto por Internet. Vea la hoja de instrucciones en la cabina de votación.

| MAYOR ALCALDE | | | |
|--|----------------------------------|----------------------------------|----------------------------------|
| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción | 3rd choice 3ra opción |
| Roger B. Schlegel | <input checked="" type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Bruce Williams | <input type="radio"/> | <input type="radio"/> | <input checked="" type="radio"/> |
| Tom Smith | <input type="radio"/> | <input checked="" type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| CITY COUNCIL MEMBER WARD 3 MIEMBRO DEL CONSEJO DE LA CIUDAD DISTRITO ELECTORAL 3 | | |
|--|--------------------------|--------------------------|
| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción |
| Dan Robinson | <input type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> |



3-972853

Online Verification Number
Número de Verificación por Internet

The receipt check is the weakest link in most E2E systems

We wanted to stress test it

Question 1:

4% of receipts checked

??% would file a dispute?

City of Takoma Park, Maryland
MUNICIPAL ELECTION
NOVEMBER 3, 2009

OFFICIAL BALLOT — WARD 3

Instructions: Vote for candidates by indicating your first-choice candidate, your second-choice candidate, and so on. You are free to rank only a first choice if you wish.

Do not fill in more than one oval per column. Do not fill in more than one oval per candidate. Do not skip numbers in the ranking sequence.

To vote for a person whose name is not printed on the ballot, write the name in the space provided and fill in one box in the column indicating your ranking of the write-in candidate.

If you make a mistake on your ballot, return it to the judge and get another.

Do not make any identifying marks on your ballot.

When you mark an oval to rank a candidate, a code will be revealed that you may later use to verify your vote online. See the instruction sheet in the voting booth.

Ciudad de Takoma Park, Maryland
ELECCIONES MUNICIPALES
3 DE NOVIEMBRE DE 2009

BOLETA OFICIAL — DISTRITO ELECTORAL 3

Instrucciones: Vote por los candidatos indicando el candidato que sea su primera opción, el candidato que sea su segunda opción, y así sucesivamente. Si lo desea, puede limitarse a seleccionar solamente al candidato que sea su primera opción.

No rellene más de una casilla por cada columna. No rellene más de una casilla por cada candidato. No salte números en la secuencia de clasificación por orden.

Para votar por una persona cuyo nombre no está impreso en la boleta, escriba el nombre en el espacio provisto y rellene una casilla en la columna para indicar el orden de clasificación del candidato que se le añadió.

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Cuando usted marque la casilla para votar por un candidato, verá un código que podrá usar posteriormente para verificar su voto por Internet. Vea la hoja de instrucciones en la cabina de votación.

| MAYOR ALCALDE | | | |
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| Tom Smith | <input type="radio"/> | <input checked="" type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

| CITY COUNCIL MEMBER WARD 3 MIEMBRO DEL CONSEJO DE LA CIUDAD DISTRITO ELECTORAL 3 | | |
|--|--------------------------|--------------------------|
| Rank candidates in order of choice Clasifique a los candidatos por orden de preferencia | 1st choice 1ra opción | 2nd choice 2da opción |
| Dan Robinson | <input type="radio"/> | <input type="radio"/> |
| Write-In Candidate/Para añadir a un candidato | <input type="radio"/> | <input type="radio"/> |



3-972853

Online Verification Number
Número de Verificación por Internet

The receipt check is the weakest link in most E2E systems

We wanted to stress test it

Question 2:

4% checked when the result was reasonable

??% when it is fraudulent?

Unexpected Result (Study 1)



Clowdflower (Canada's MTurk), 841 participants

Asked people to vote for a charity to receive a donation (\$50 CAD)

Charity vote!

As a thank you for participating, please vote for one of the five charities listed below.

We will donate \$50 to the charity that is selected by the largest percentage of participants, and let you know the outcome of the vote.

Please select one of the following:

- United Way
- Feeding America (food banks)
- Livestrong
- National Rifle Association
- Church of Scientology
- No Thanks/no vote

603 recipients completed their ballot and received an email with a link to the results

84 clicked

Half (42) were shown the correct result (Feeding America) and **22** checked their receipt



We inverted the results, reporting that the Church of Scientology won despite it receiving the least votes

603 recipients completed their ballot and received an email with a link to the results

84 clicked

Half (42) were shown the correct result (Feeding America) and **22** checked their receipt

603 recipients completed their ballot and received an email with a link to the results

84 clicked

Half (42) were shown the correct result (Feeding America) and **22** checked their receipt

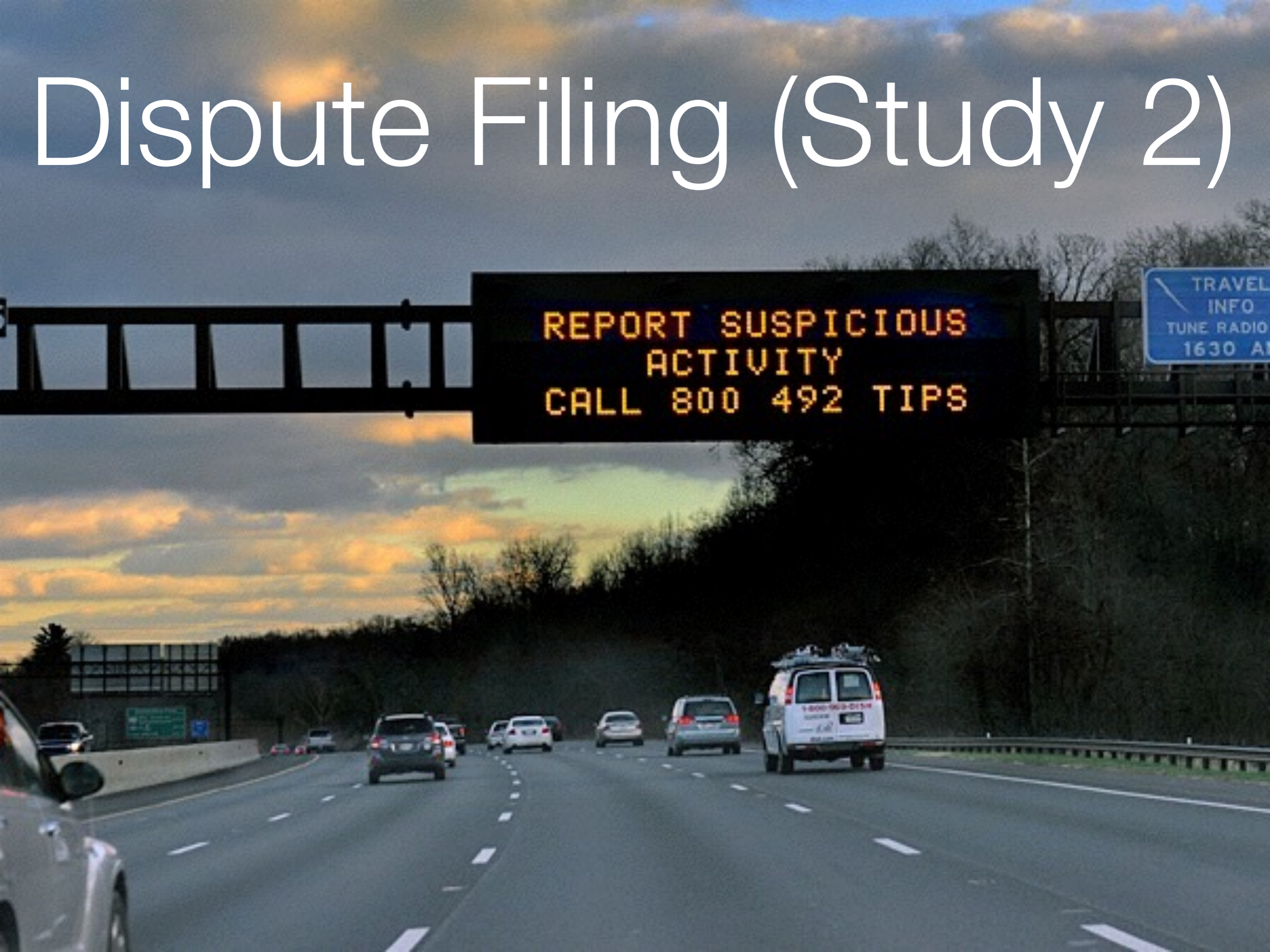
Half (42) were shown the incorrect result (Scientology) and **32** checked their receipt

The result was significant

Dispute Filing (Study 2)

REPORT SUSPICIOUS
ACTIVITY
CALL 800 492 TIPS

TRAVEL
INFO
TUNE RADIO
1630 AM



Cloudflower, 755 participants

We tried to get an upper-bound on the number of reports:

- 1) Unexpected result
- 2) We primed the voter to anticipate the potential for error
- 3) We used an internet-savvy crowd

We provide each voter who checked (7.4%) with an *incorrect* confirmation code and the ability to report it

Your confirmation code is:

CRB

If the confirmation code above is the same as your records, your vote has been counted correctly.

If the confirmation code above is the NOT same as your records, your vote has been counted INCORRECTLY.

To report a problem, click the link below:

[Report an error](#)

Finish

We provide each voter who checked (7.4%) with an *incorrect* confirmation code and the ability to report it

Report a problem

Please use the space below to report an issue with your vote:

The code was incorrect

Please input your confirmation code to assist in resolving this dispute:

TWA

Finish

How many voters reported the error?

How many voters reported the error?

0.5%

(4 voters out of 755)

Not sure why the number is so low

Theories:


- 1) Bystander effect - someone else will report it
- 2) Knowledge gap - don't trust their own judgement



1,212,629

1,212,317

7.5% file disputes: detect fraud with 99.99%

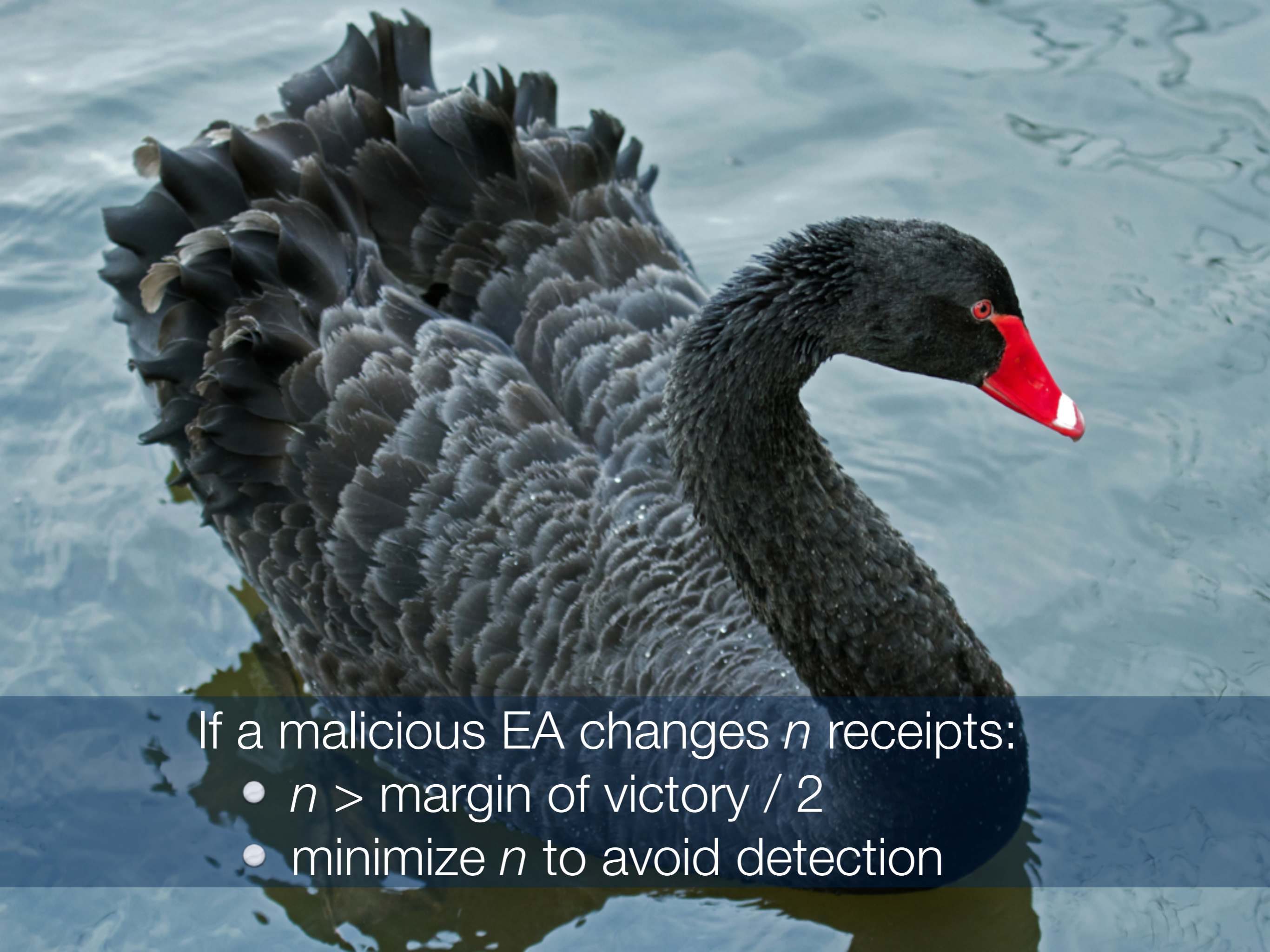


1,212,629

1,212,317

7.5% file disputes: detect fraud with 99.99%
0.5% file disputes: detect fraud with 43.25%





- If a malicious EA changes n receipts:
- $n > \text{margin of victory} / 2$
 - minimize n to avoid detection



Replication



Counter-measures

Thank You

Questions?

