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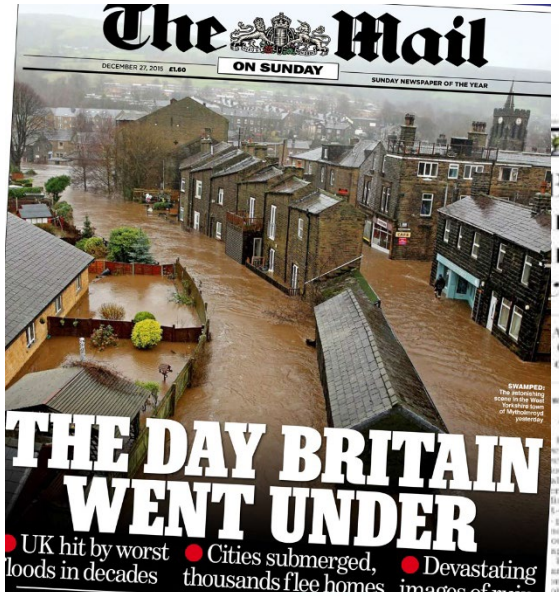
11 July 2023 // Ecological Economics in Tuscany

Experimental Economics for Disaster Preparedness

Jantsje Mol // www.jantsje.nl // @jantsjemol

Floods & Hurricanes



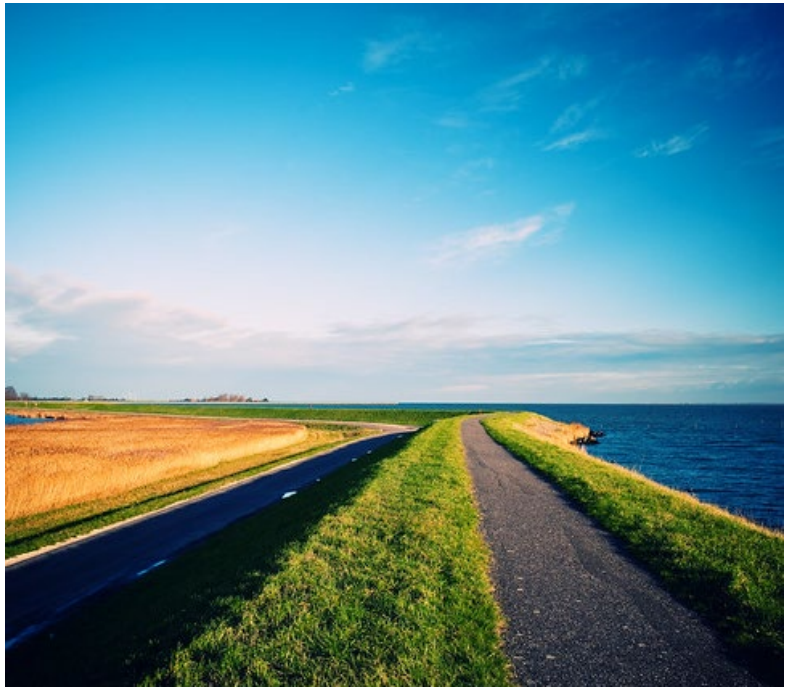
'Duitse schade door overstromingen bedraagt mogelijk tot 30 miljard euro'

Watersnood Op basis van een schatting van de overstromingsschade, heeft de premier van Noordrijn-Westfalen Armin Laschet een federaal herstelpakket van 20 tot 30 miljard euro geëist.

Flóri Hofman · 9 augustus 2021 · Leestijd 1 minuut

Flood preparedness

- Flood defenses



Flood preparedness

- Flood defenses
- Flood insurance

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- Flood defenses
- Flood insurance
- Individual flood risk reduction measures

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  > self-protection = reducing probability of an event

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  - **> self-insurance = reducing damage in case of an event**

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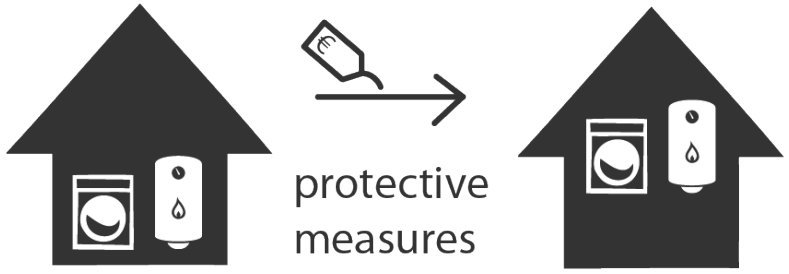

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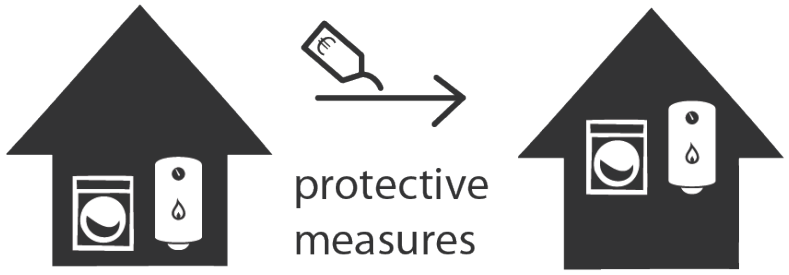

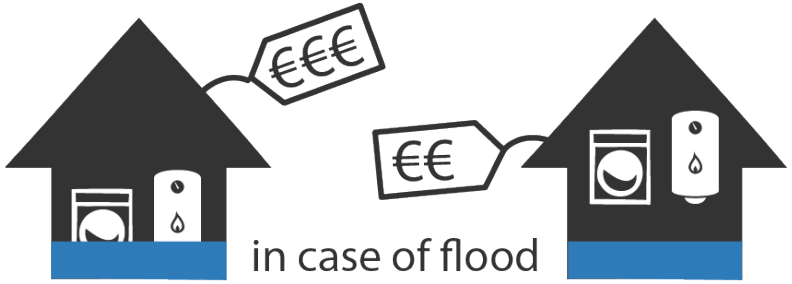

Flood preparedness

- Flood defenses
- Flood insurance
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  - > self-protection = reducing probability of an event
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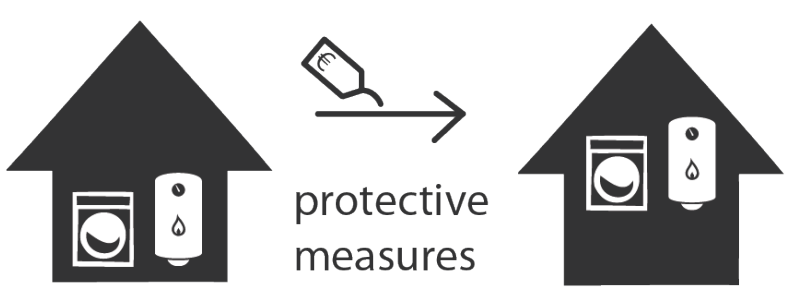
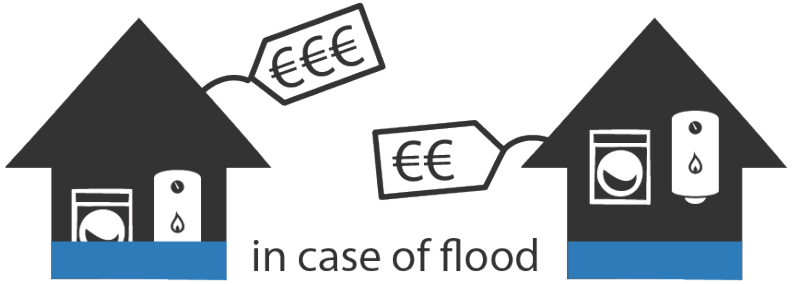
These measures are often **cost effective in the long run**





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Measuring flood preparedness

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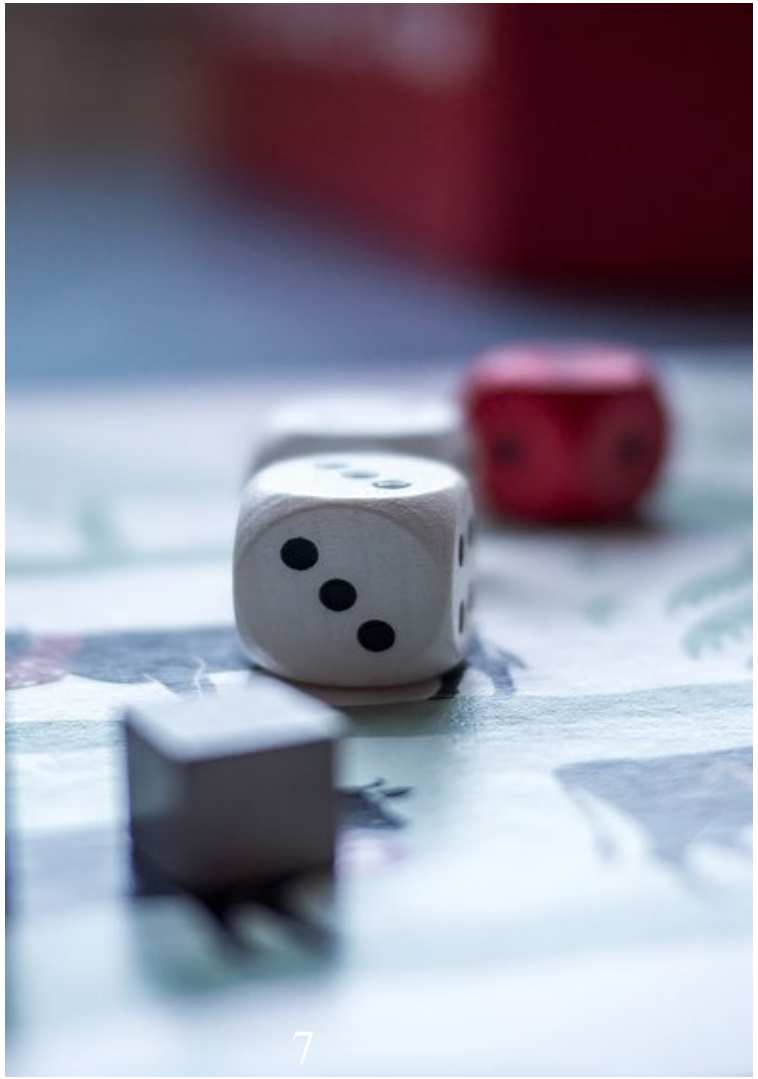
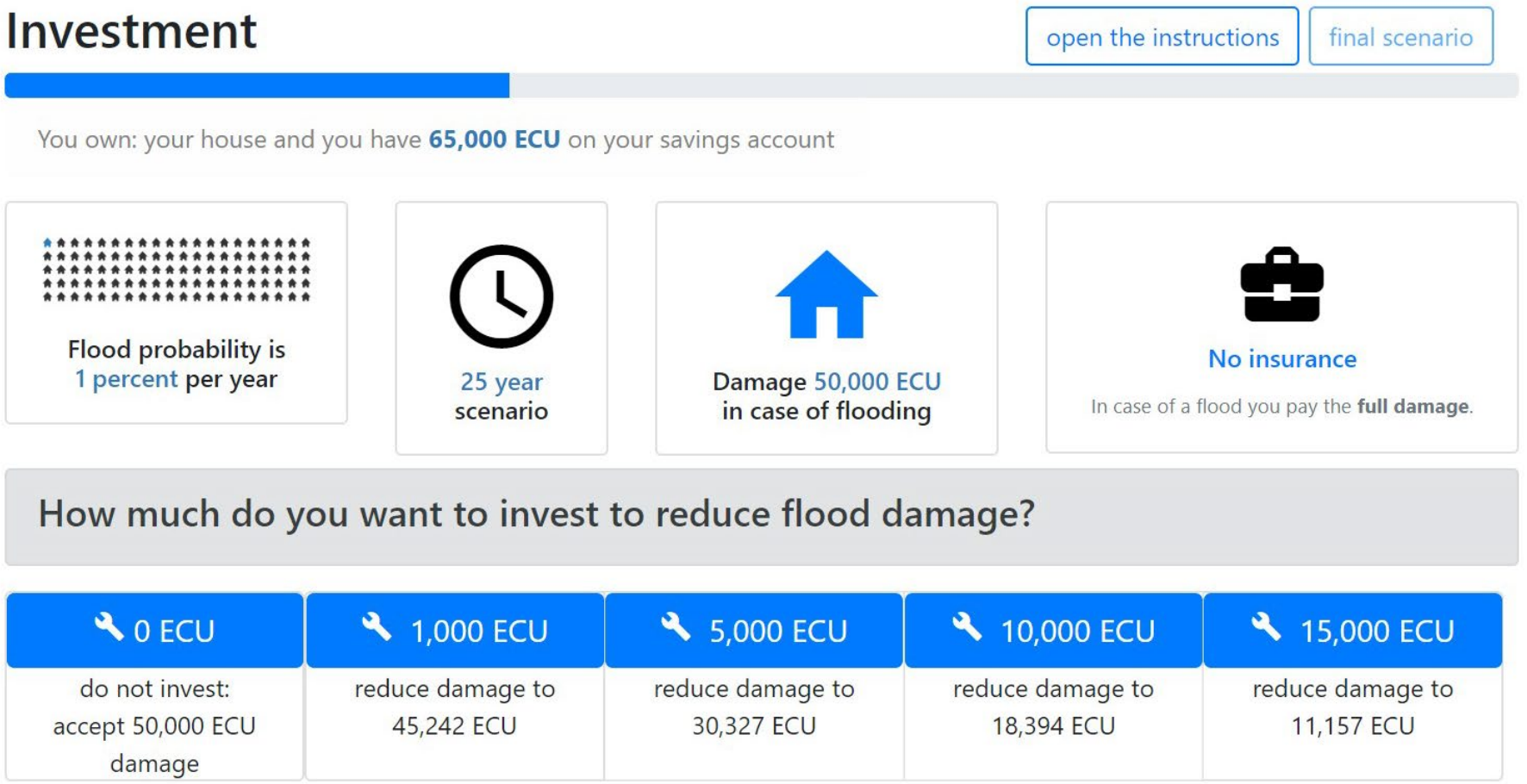


Measuring flood preparedness: the game



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Measuring flood preparedness: the game

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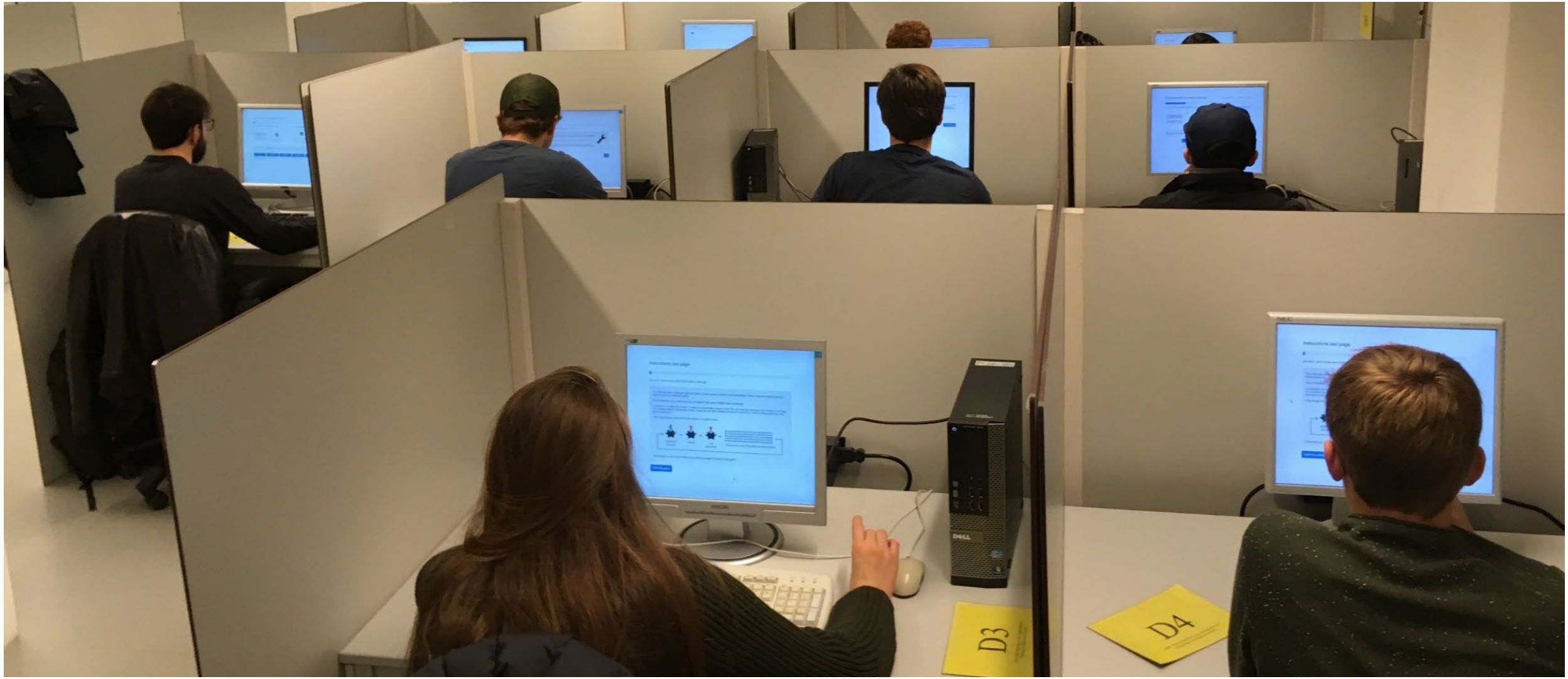
Measuring flood preparedness (lab: test incentives)



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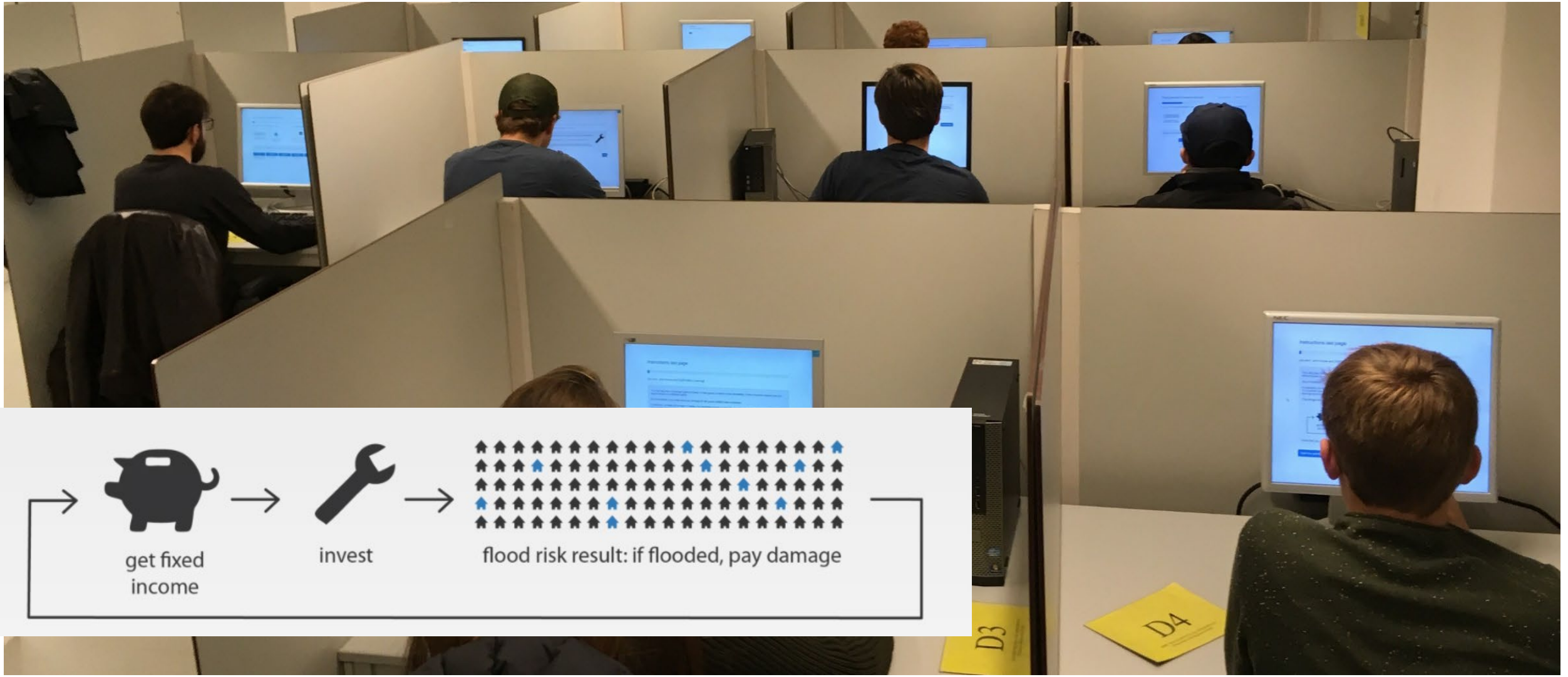

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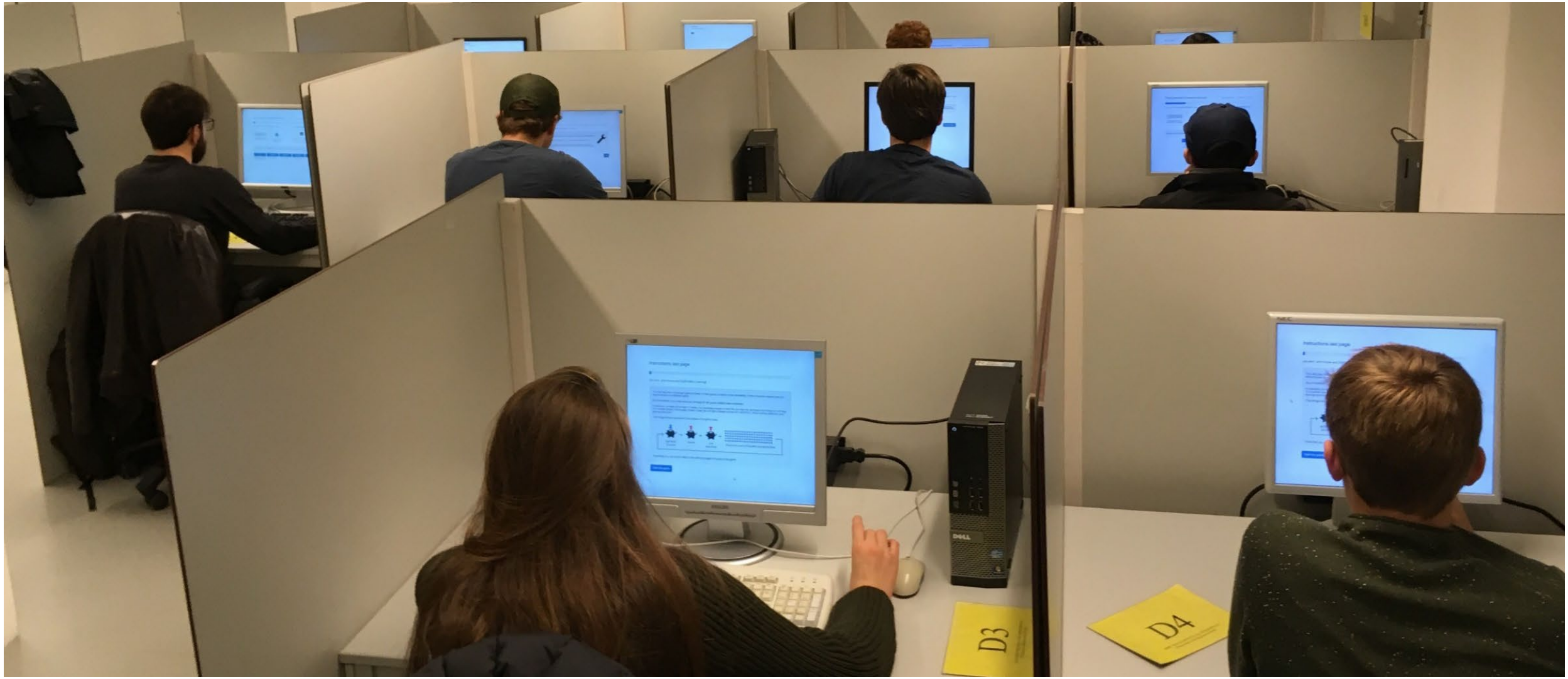

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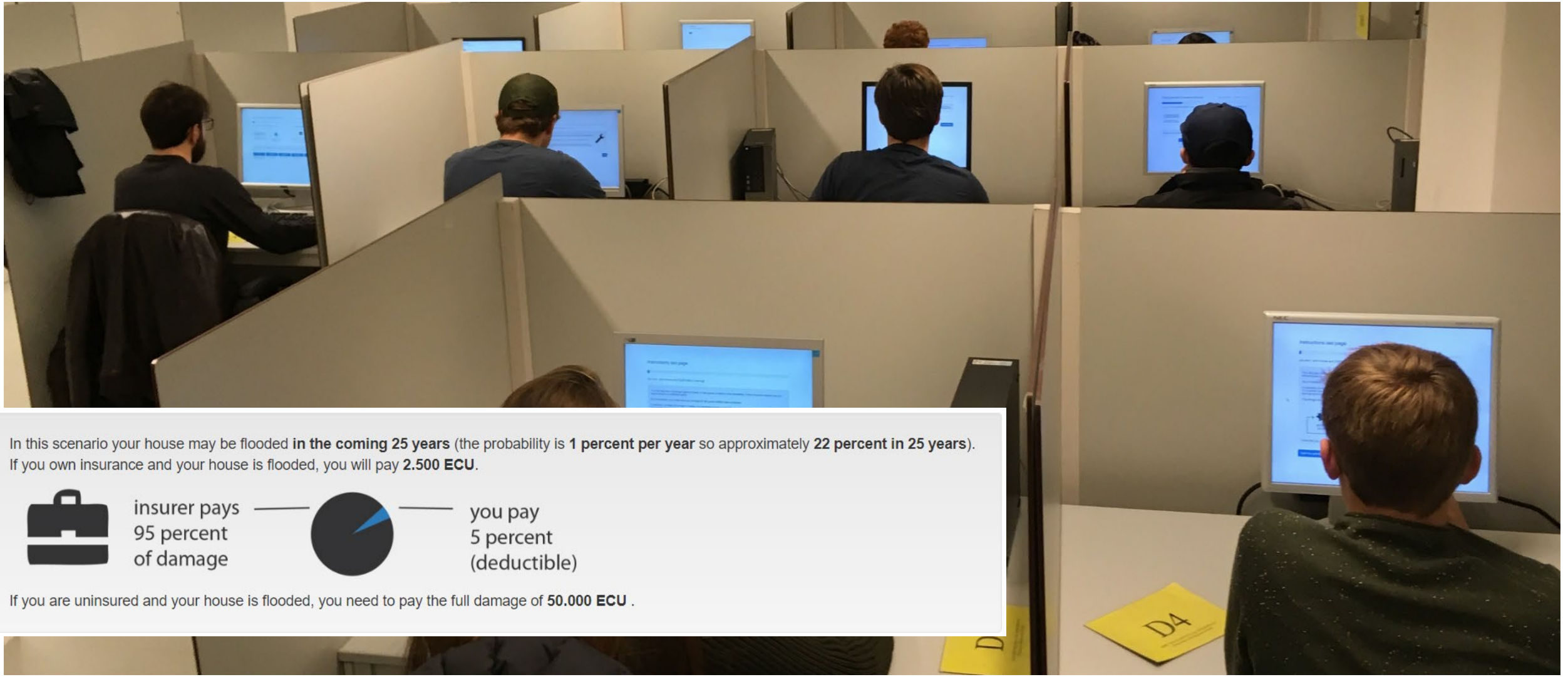

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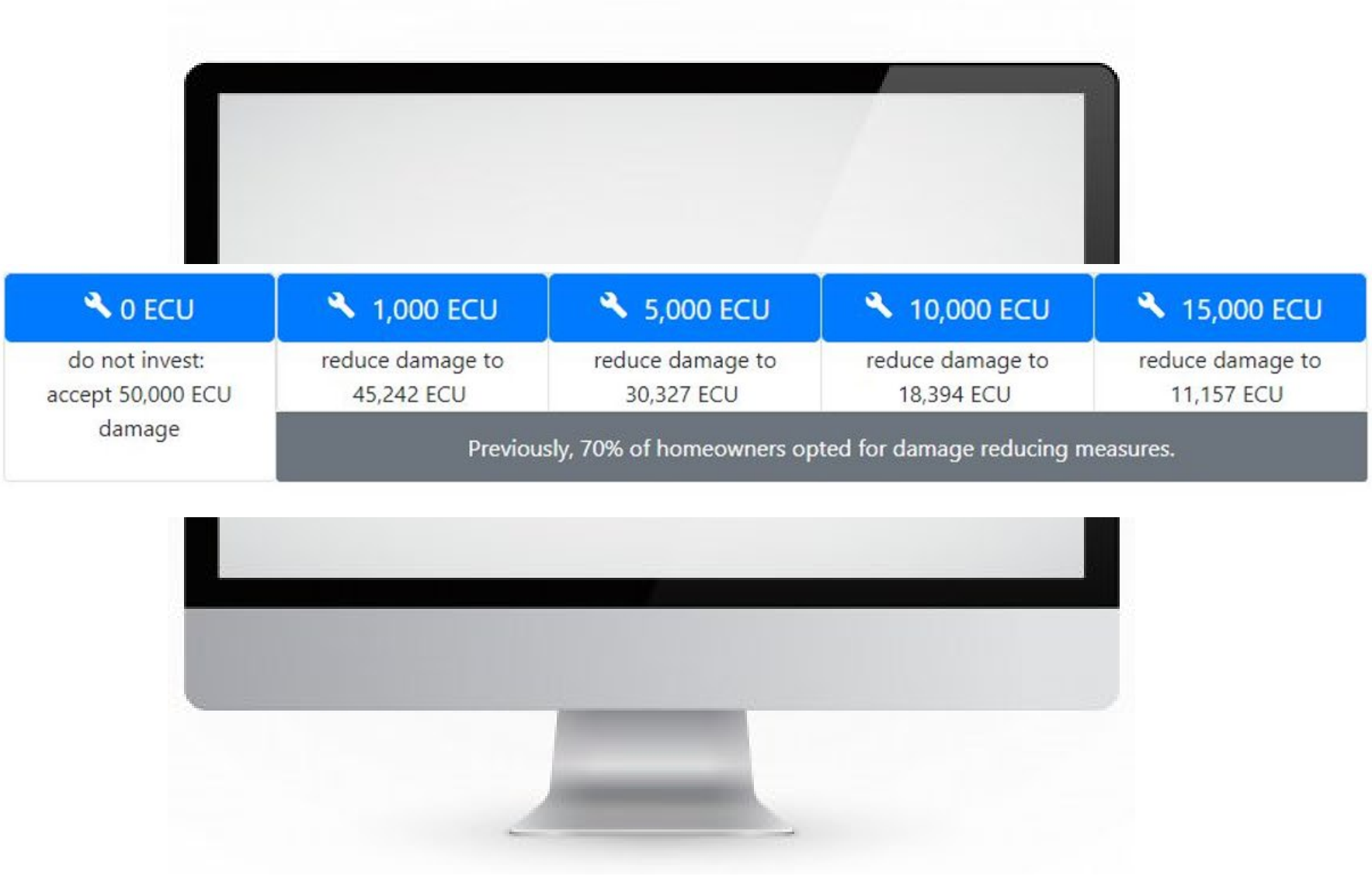

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Improving flood preparedness with Virtual Reality

Why Virtual Reality technology?

Important predictors of flood preparedness

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Important predictors of flood preparedness

- Experience (Grothmann and Reusswig, 2006; Guo and Li, 2016; Osberghaus, 2017)
  - Water levels
  - Damage

Why Virtual Reality technology?

Important predictors of flood preparedness

- Experience (Grothmann and Reusswig, 2006; Guo and Li, 2016; Osberghaus, 2017)
  - Water levels
  - Damage
- Coping values (Bubeck et al., 2013)
  - Response efficacy *(perceived effectiveness of measures)*
  - Self-efficacy (*subjective feeling of being able to install measures)*

Virtual Reality experience

Sandbag = stack sandbags to protect home

(a) *Sandbag*

Virtual Reality experience

Sandbag = stack sandbags to protect home
Protected = check protected home from inside

(a) *Sandbag*

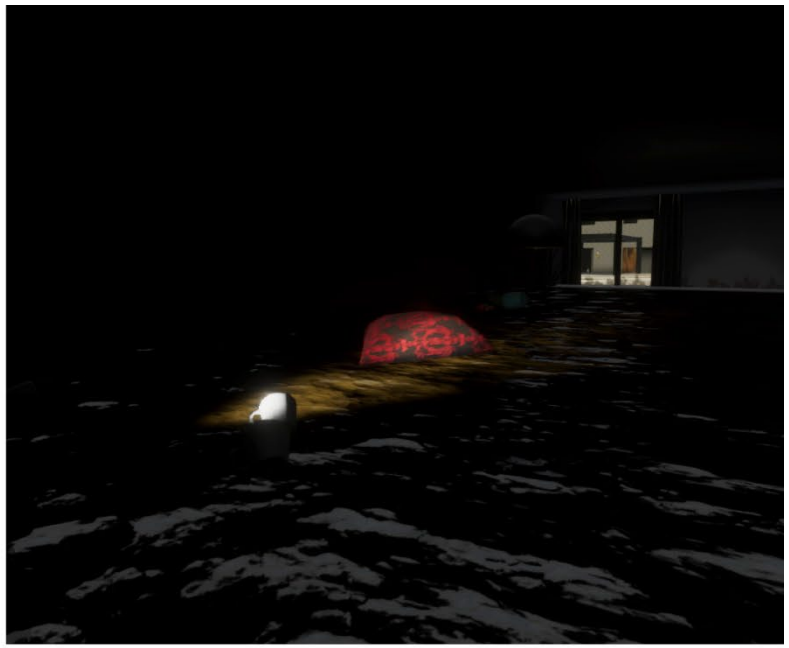
(b) *Protected*

Virtual Reality experience

Sandbag = stack sandbags to protect home
Protected = check protected home from inside
Neighbors = check unprotected home from neighbors

(a) *Sandbag*

(b) *Protected*



(c) *Neighbors*

Video at https://vimeo.com/482506190

Experimental design

Homeowners from the Amsterdam area

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Control group $n = 276$ at home

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VR group $n = 108$ in the lab + follow-up 4 weeks later ($n = 78$)

Experimental design

Homeowners from the Amsterdam area

Control group $n = 276$ at home

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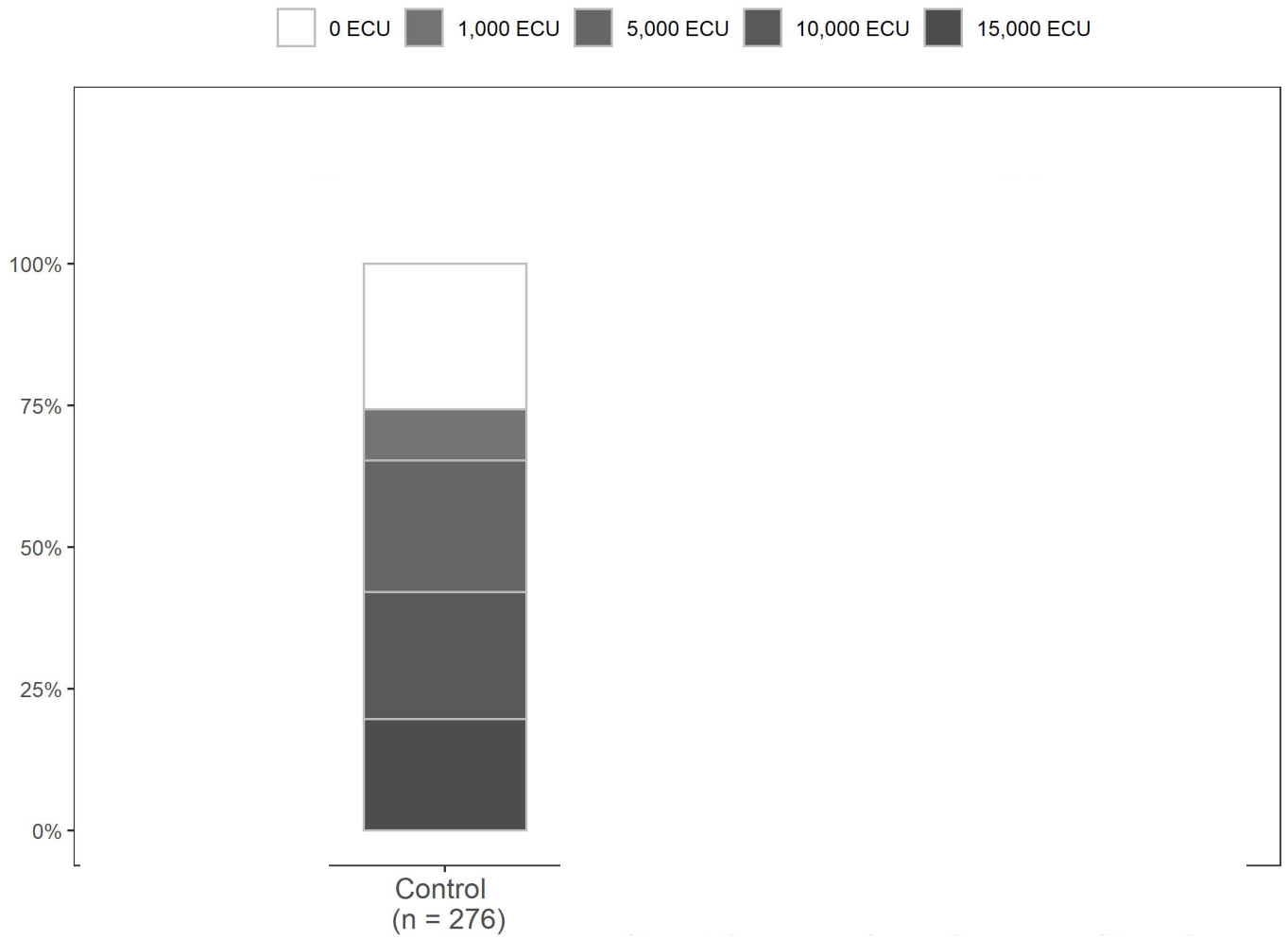
Dependent variables:

- Flood risk investment game
- Risk perception

Results flood risk investment



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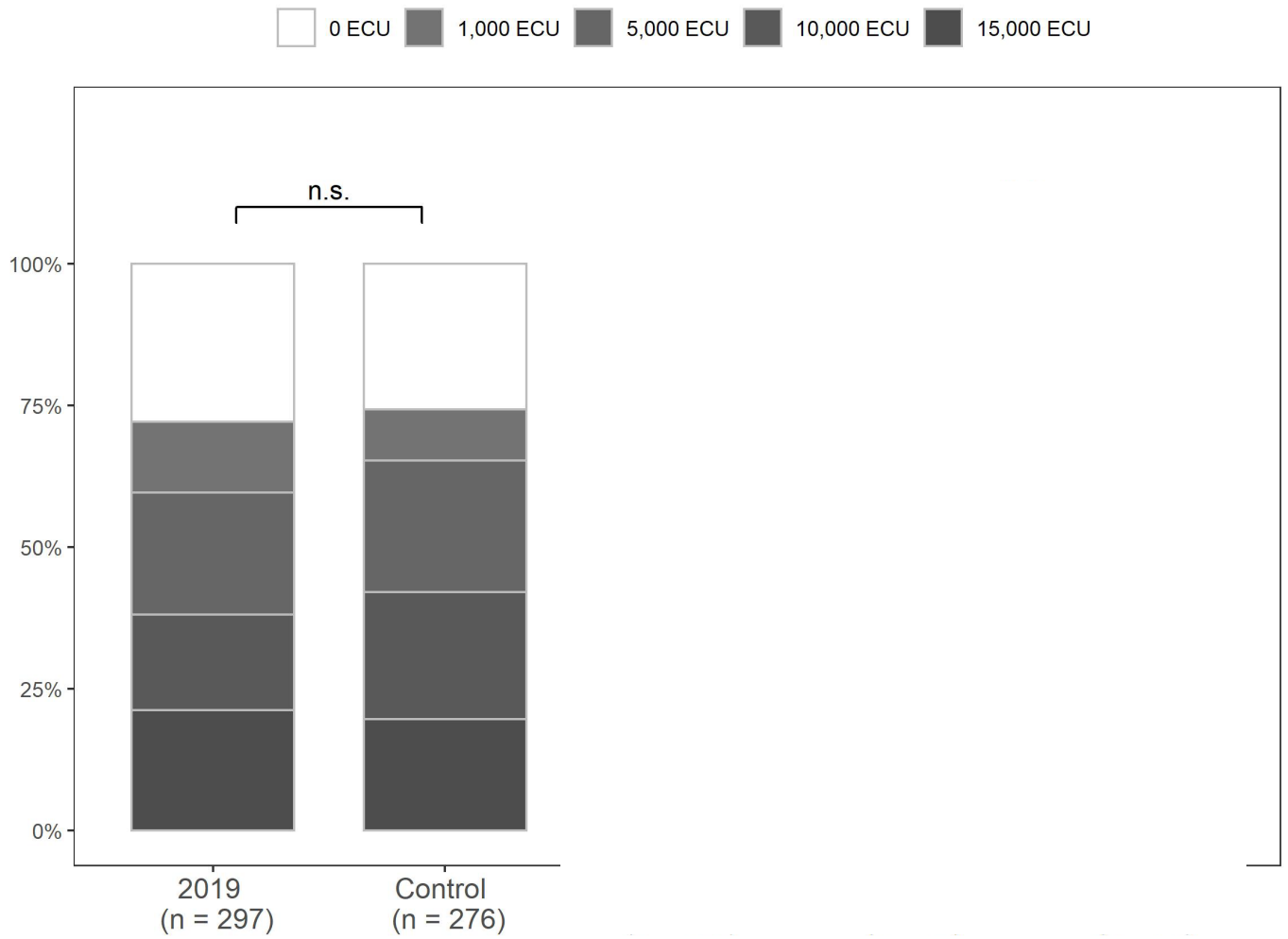

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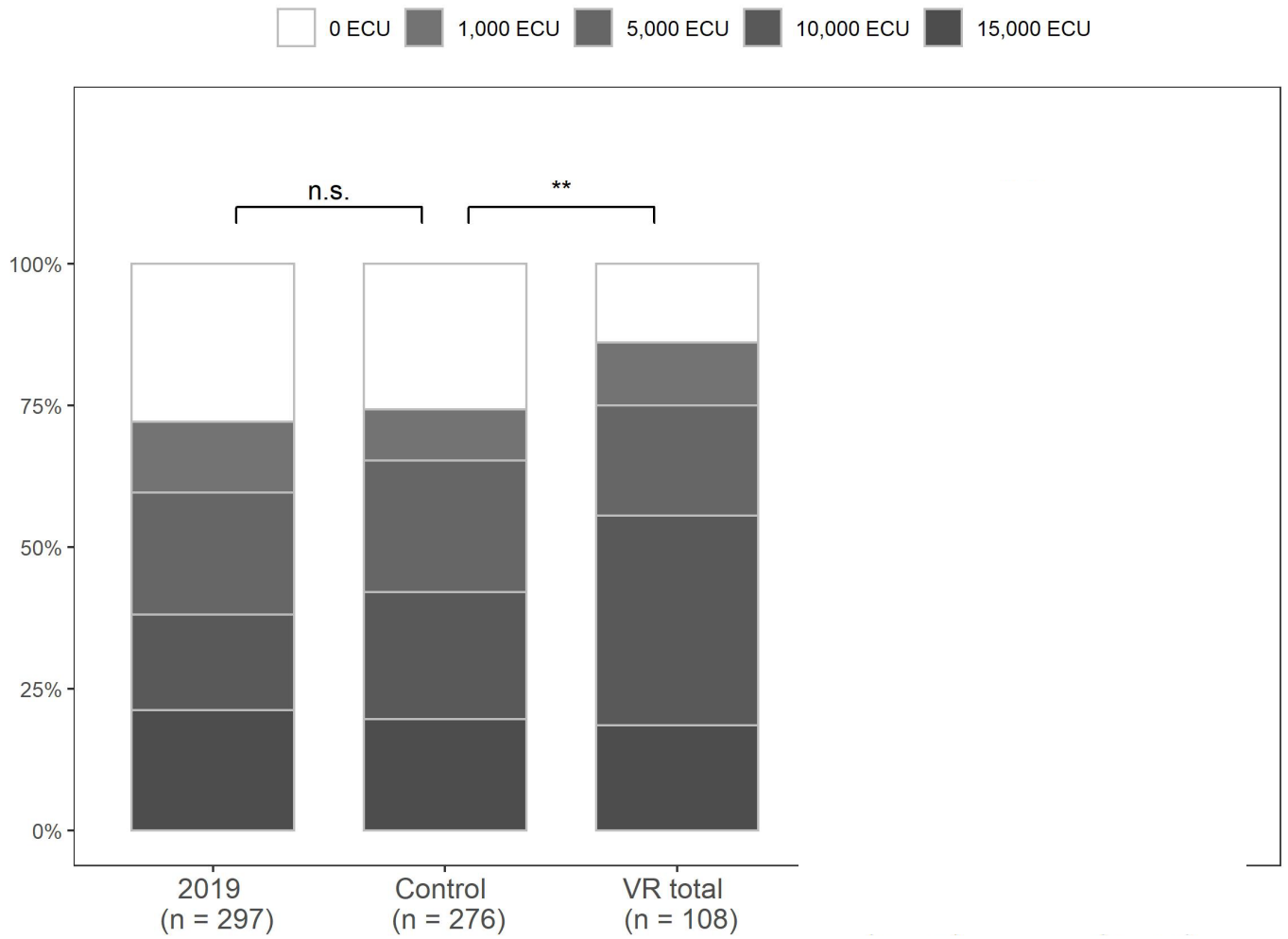

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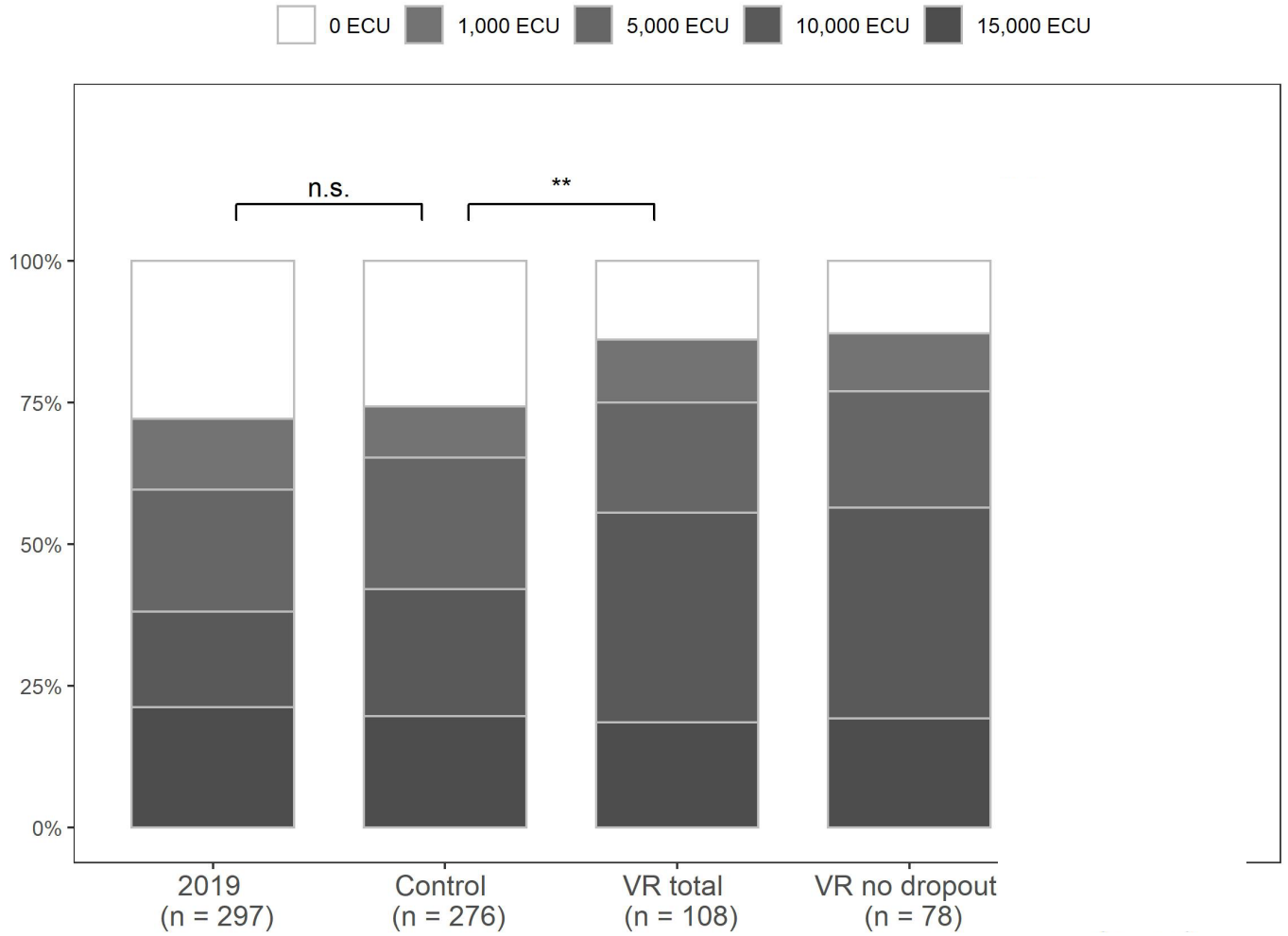

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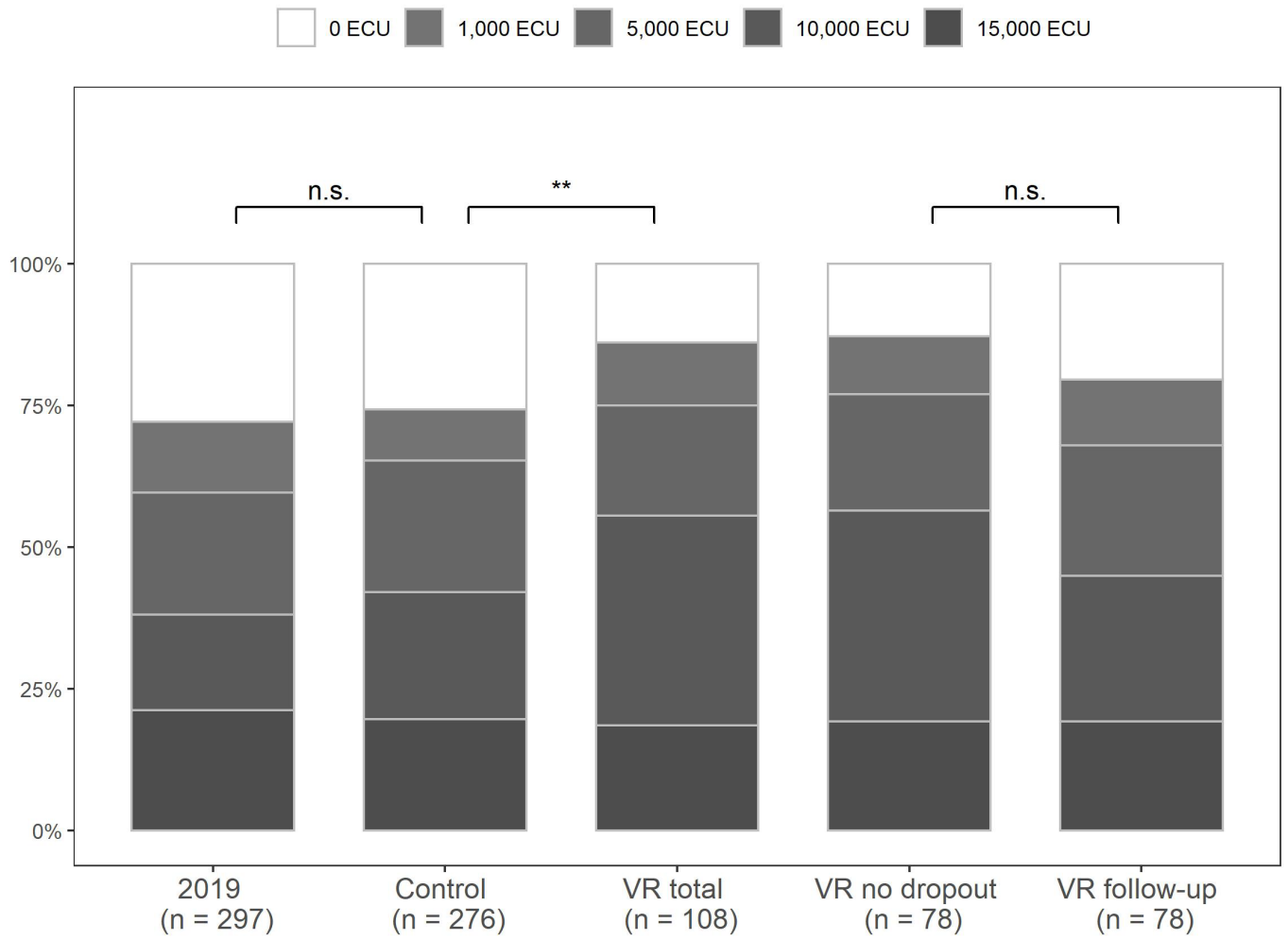
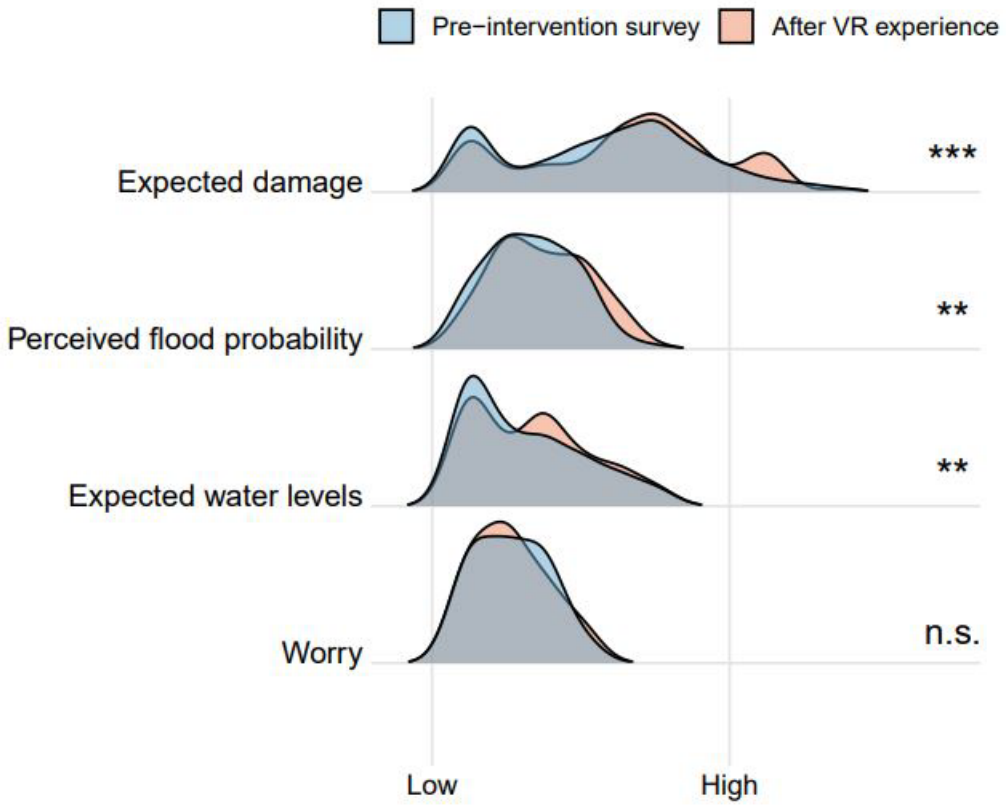
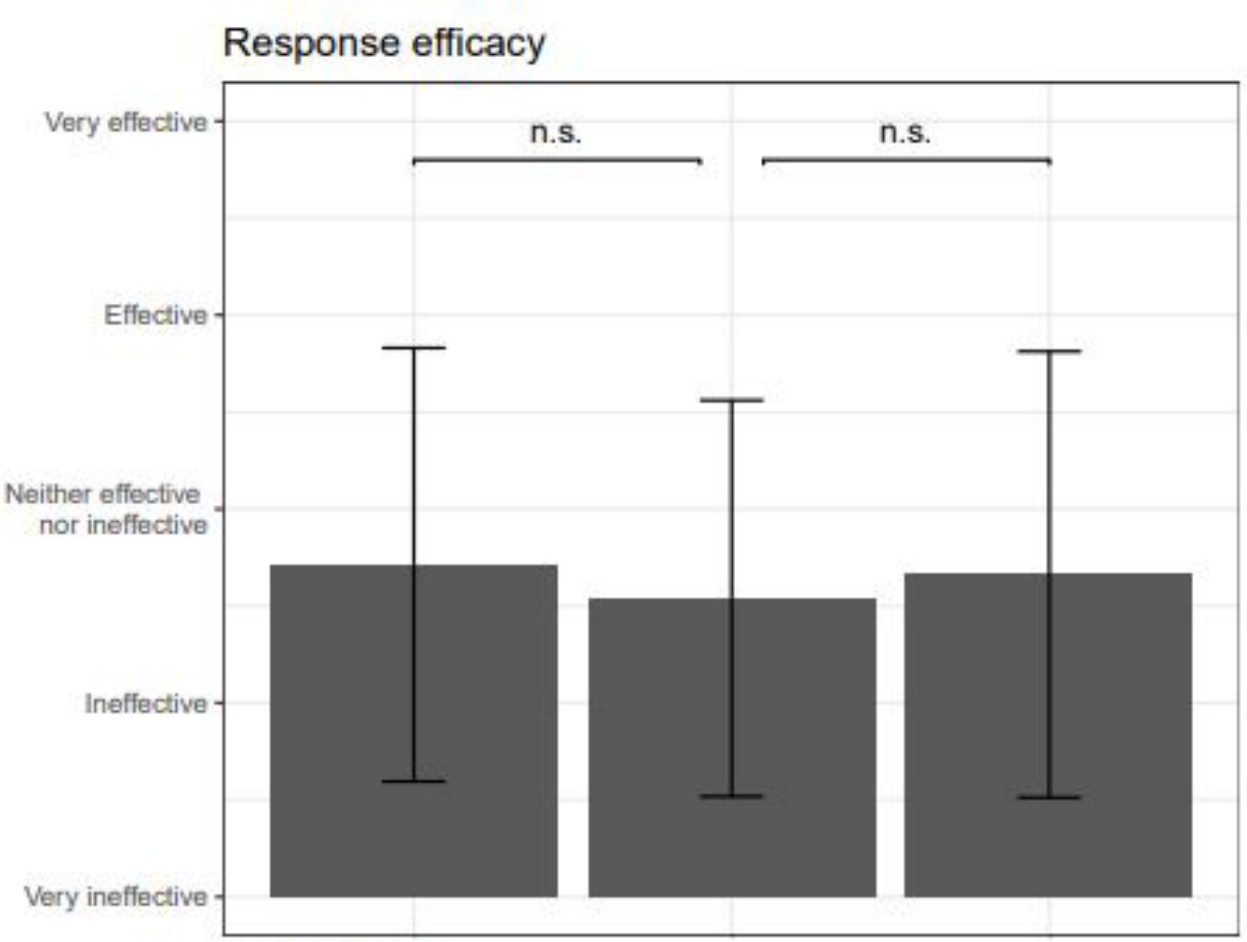


Results risk perception

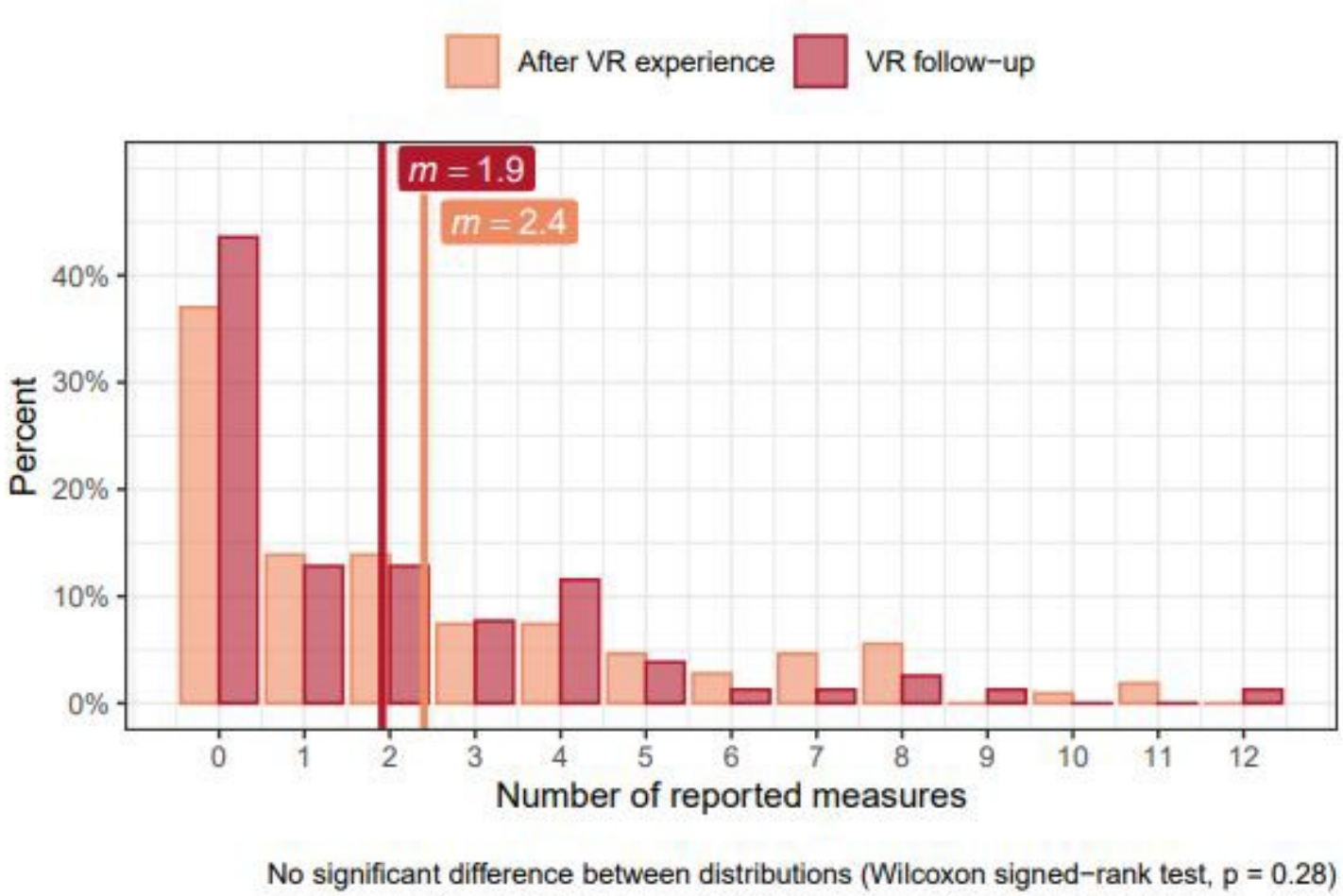


Stars indicate significance of Wilcoxon signed−rank tests recruitment survey vs. after VR experience

Null results (1)



Null results (2)



No significant difference between distributions (Wilcoxon signed-rank test, p = 0.28)

Discussion

- Low tech next step?
  - e.g. augmented reality
- High expectations may hamper the effect
- Decrease in effect over time
- Pure lab-effect?

Thanks to my participants!

Participant (50): "Oh no, my precious BBQ!"

Thanks to my participants!

Participant (50): "Oh no, my precious BBQ!"

Participant (65) searches for wallet in (real-life) pockets and realizes it is not there…
"Oh well, I am not carrying my creditcard so we are good!"

Saffir-Simpson Hurricane Scale

Only represents *wind* hazards

Saffir–Simpson scale

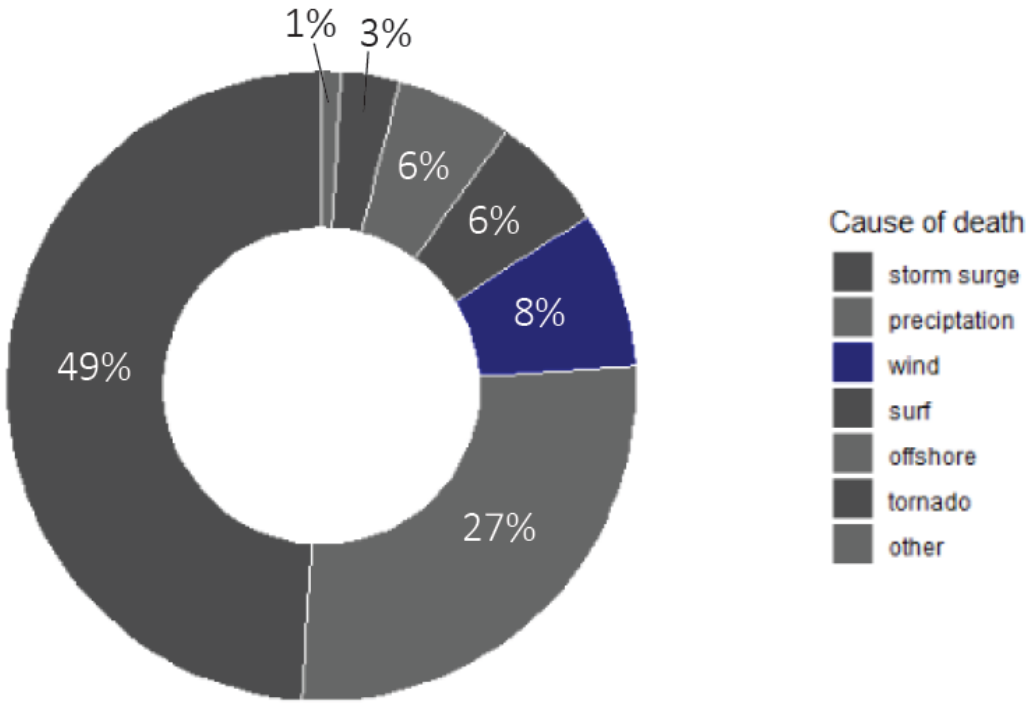
Category	Wind speeds			
	m/s	knots (kn)	mph	km/h
Five	≥ 70 m/s	≥ 137 kn	≥ 157 mph	≥ 252 km/h
Four	58–70 m/s	113–136 kn	130–156 mph	209–251 km/h
Three	50–58 m/s	96–112 kn	111–129 mph	178–208 km/h
Two	43–49 m/s	83–95 kn	96–110 mph	154–177 km/h
One	33–42 m/s	64–82 kn	74–95 mph	119–153 km/h

Related classifications

Tropical storm	18–32 m/s	34–63 kn	39–73 mph	63–118 km/h
Tropical depression	≤ 17 m/s	≤ 33 kn	≤ 38 mph	≤ 62 km/h

Saffir-Simpson Hurricane Scale

Only represents *wind* hazards



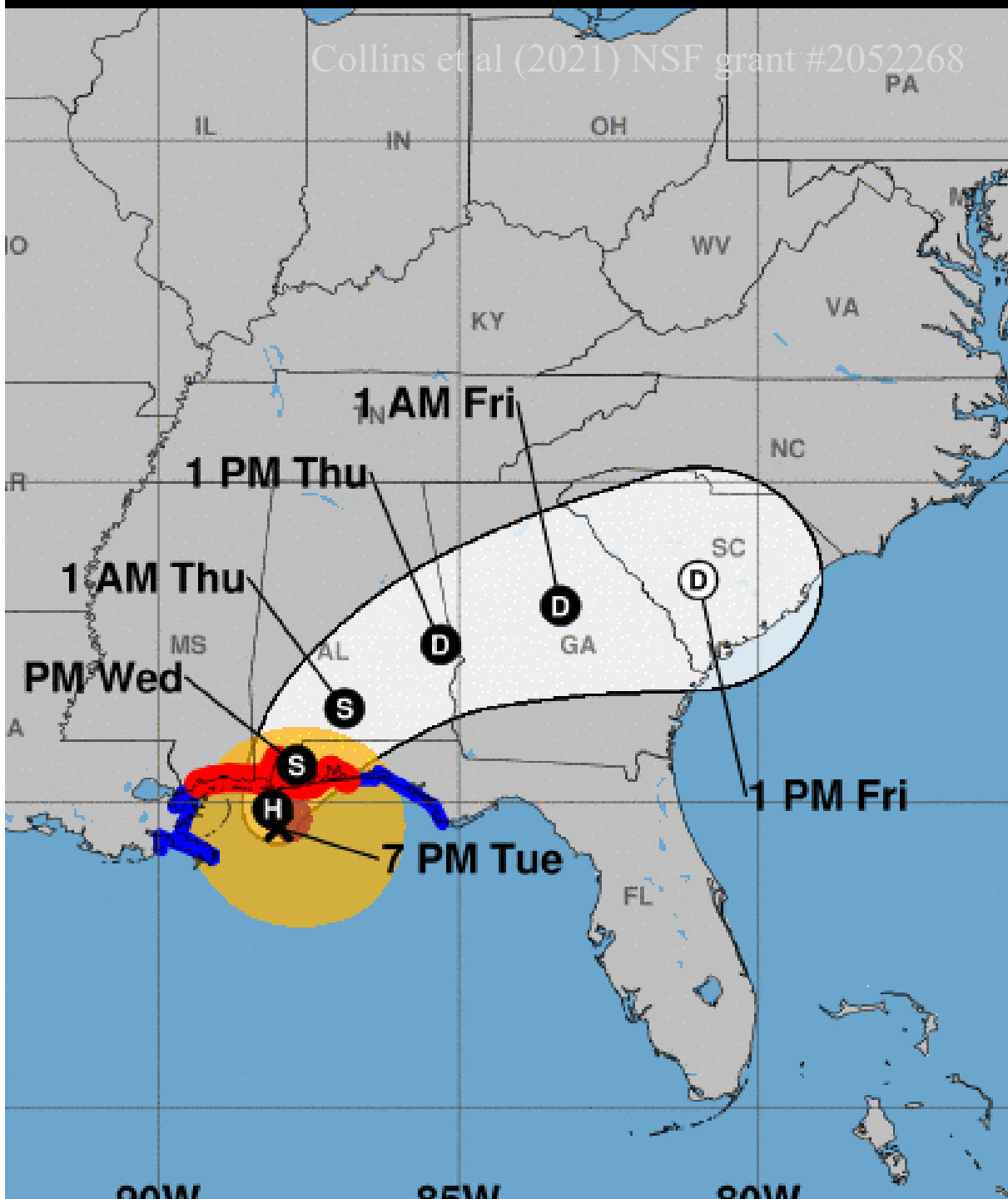
ORIGINAL SCALE

Saffir-Simpson Hurricane Wind Scale (SSWHS)

based on
wind

Saffir-Simpson gone bad

Example: Hurricane Sally



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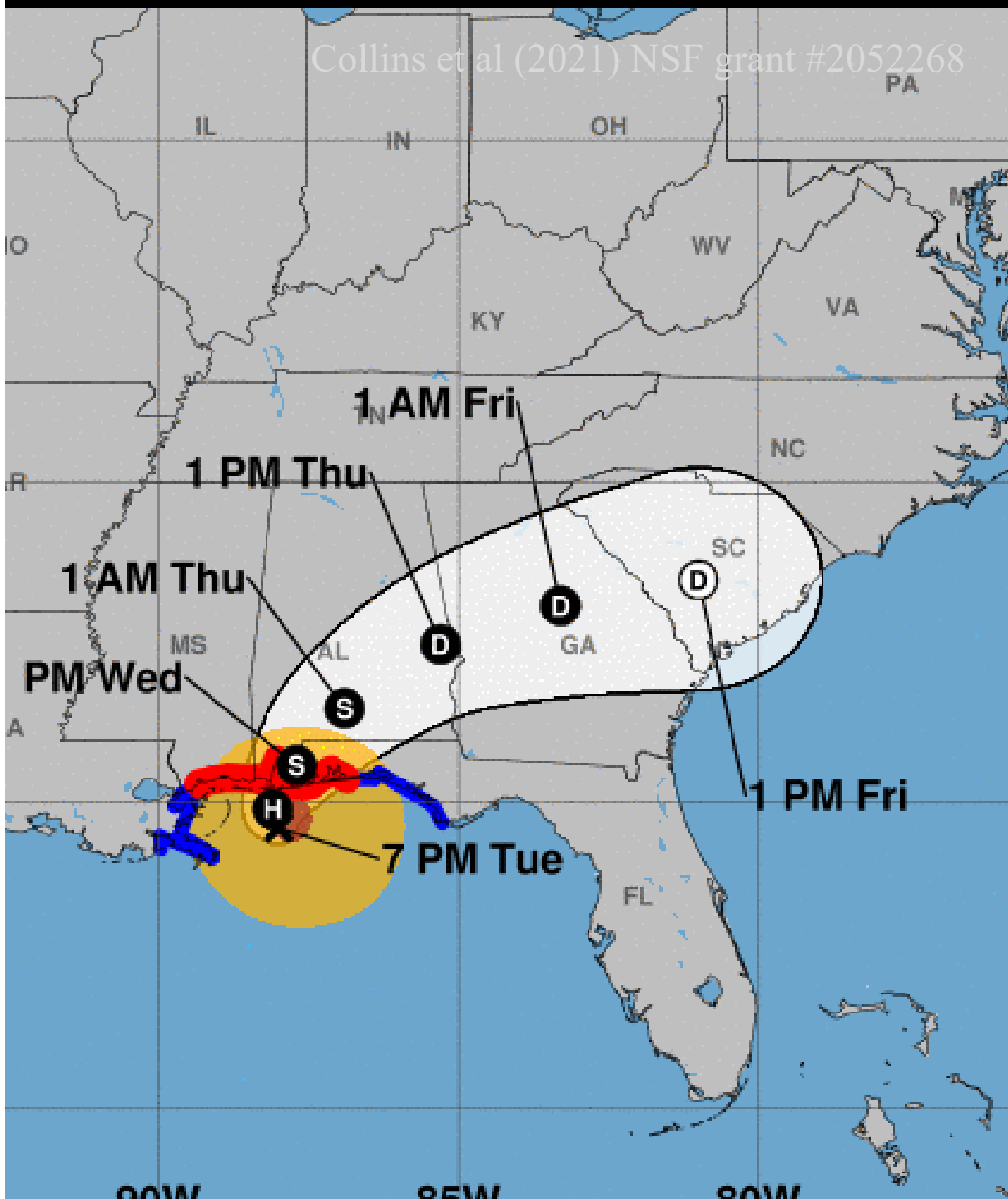
Saffir-Simpson gone bad

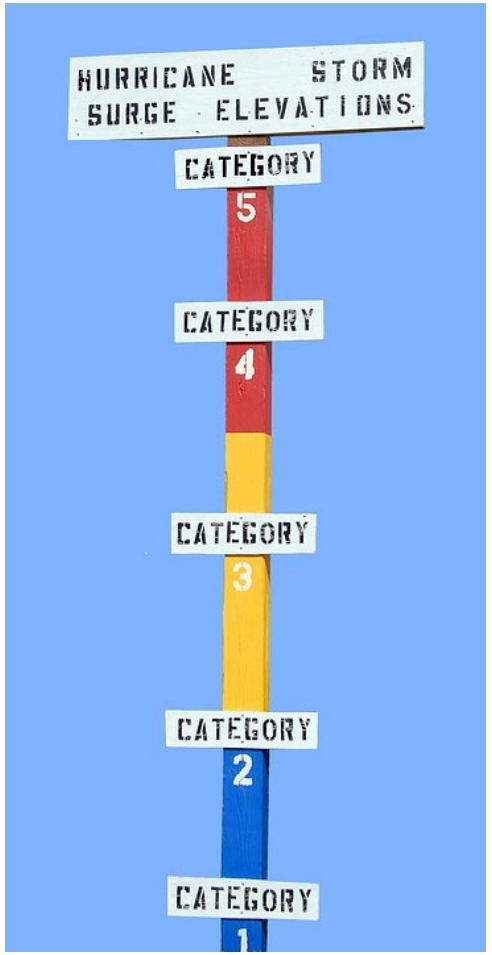
Example: Hurricane Sally

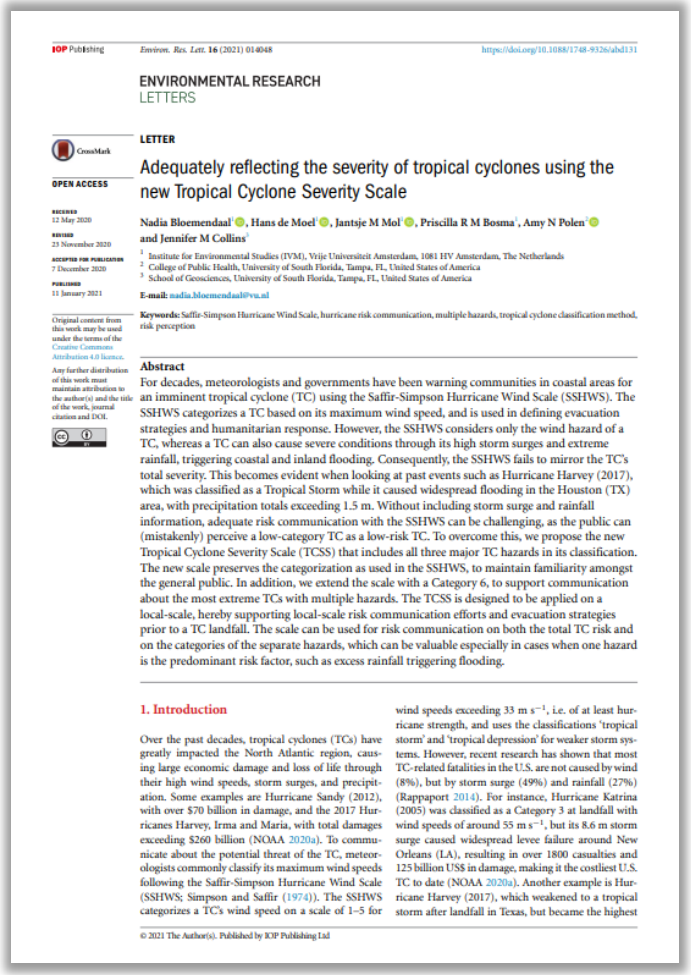
"If it would have been a three or higher, we would have left"



Tropical Cyclone Severity Scale (TCSS)

- One category for all major hazards





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ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Adequately reflecting the severity of tropical cyclones using the new Tropical Cyclone Severity Scale

Nadia Bloemendaal[1], Hans de Moel[1], Jantsje M Mol[1], Priscilla R M Bosma[1], Amy N Polen[2] and Jennifer M Collins[3]

[1] Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, 1081 HV Amsterdam, The Netherlands
[2] College of Public Health, University of South Florida, Tampa, FL, United States of America
[3] School of Geosciences, University of South Florida, Tampa, FL, United States of America

E-mail: nadia.bloemendaal@vu.nl

Keywords: Saffir-Simpson Hurricane Wind Scale, hurricane risk communication, multiple hazards, tropical cyclone classification method, risk perception

OPEN ACCESS

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PUBLISHED 11 January 2021

Abstract

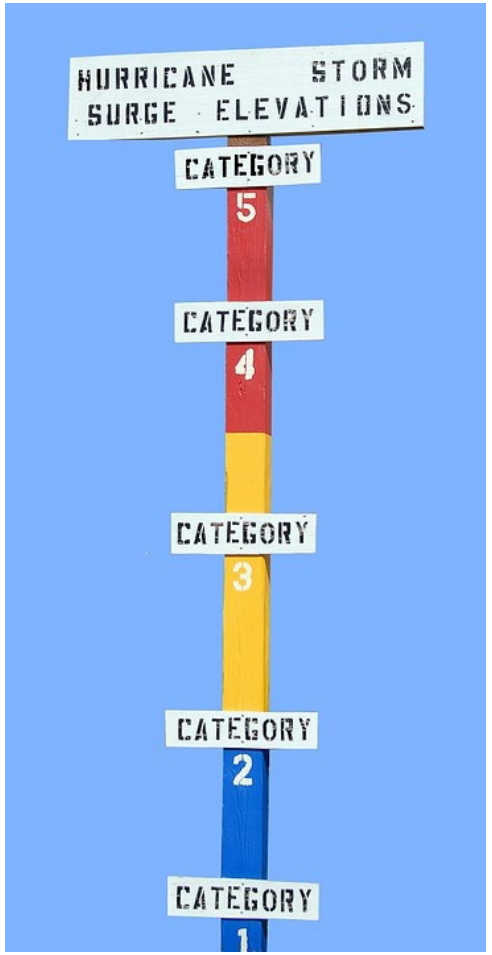
For decades, meteorologists and governments have been warning communities in coastal areas for an imminent tropical cyclone (TC) using the Saffir-Simpson Hurricane Wind Scale (SSHWS). The SSHWS categorizes a TC based on its maximum wind speed, and is used in defining evacuation strategies and humanitarian response. However, the SSHWS considers only the wind hazard of a TC, whereas a TC can also cause severe conditions through its high storm surges and extreme rainfall, triggering coastal and inland flooding. Consequently, the SSHWS fails to mirror the TC's total severity. This becomes evident when looking at past events such as Hurricane Harvey (2017), which was classified as a Tropical Storm while it caused widespread flooding in the Houston (TX) area, with precipitation totals exceeding 1.5 m. Without including storm surge and rainfall information, adequate risk communication with the SSHWS can be challenging, as the public can (mistakenly) perceive a low-category TC as a low-risk TC. To overcome this, we propose the new Tropical Cyclone Severity Scale (TCSS) that includes all three major TC hazards in its classification. The new scale preserves the categorization as used in the SSHWS, to maintain familiarity amongst the general public. In addition, we extend the scale with a Category 6, to support communication about the most extreme TCs with multiple hazards. The TCSS is designed to be applied on a local-scale, hereby supporting local-scale risk communication efforts and evacuation strategies prior to a TC landfall. The scale can be used for risk communication on both the total TC risk and on the categories of the separate hazards, which can be valuable especially in cases when one hazard is the predominant risk factor, such as excess rainfall triggering flooding.

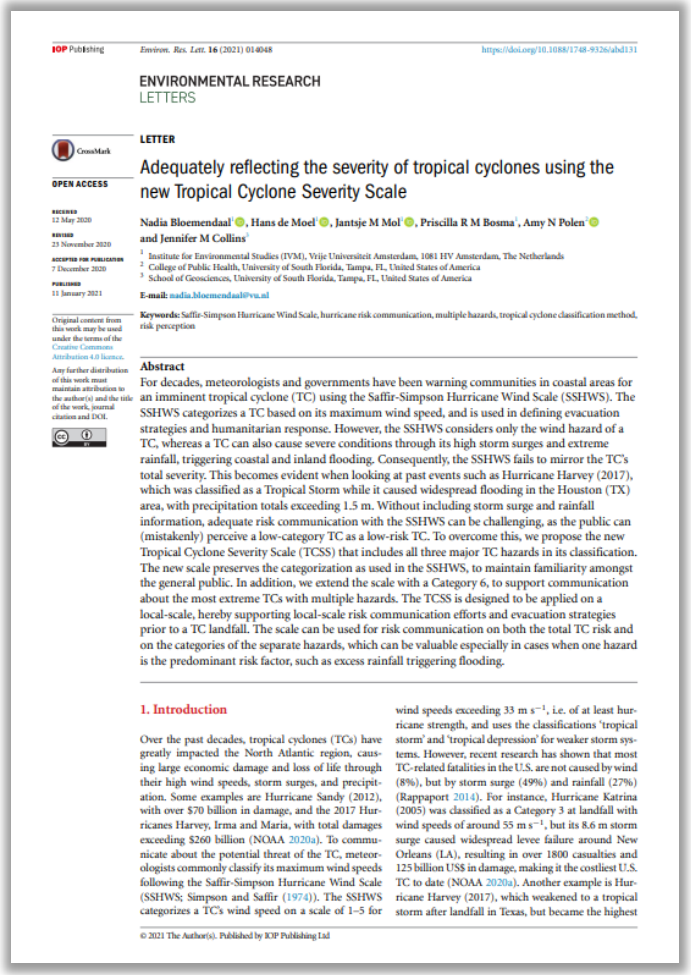
1. Introduction

Over the past decades, tropical cyclones (TCs) have greatly impacted the North Atlantic region, causing large economic damage and loss of life through their high wind speeds, storm surges, and precipitation. Some examples are Hurricane Sandy (2012), with over $70 billion in damage, and the 2017 Hurricanes Harvey, Irma and Maria, with total damages exceeding $260 billion (NOAA 2020a). To communicate about the potential threat of the TC, meteorologists commonly classify its maximum wind speeds following the Saffir-Simpson Hurricane Wind Scale (SSHWS; Simpson and Saffir (1974)). The SSHWS categorizes a TC's wind speed on a scale of 1–5 for wind speeds exceeding 33 m s^{-1}, i.e. of at least hurricane strength, and uses the classifications 'tropical storm' and 'tropical depression' for weaker storm systems. However, recent research has shown that most TC-related fatalities in the U.S. are not caused by wind (8%), but by storm surge (49%) and rainfall (27%) (Rappaport 2014). For instance, Hurricane Katrina (2005) was classified as a Category 3 at landfall with wind speeds of around 55 m s^{-1}, but its 8.6 m storm surge caused widespread levee failure around New Orleans (LA), resulting in over 1800 casualties and 125 billion US$ in damage, making it the costliest U.S. TC to date (NOAA 2020a). Another example is Hurricane Harvey (2017), which weakened to a tropical storm after landfall in Texas, but became the highest

Tropical Cyclone Severity Scale (TCSS)

- One category for all major hazards
- Categories 0 – 5





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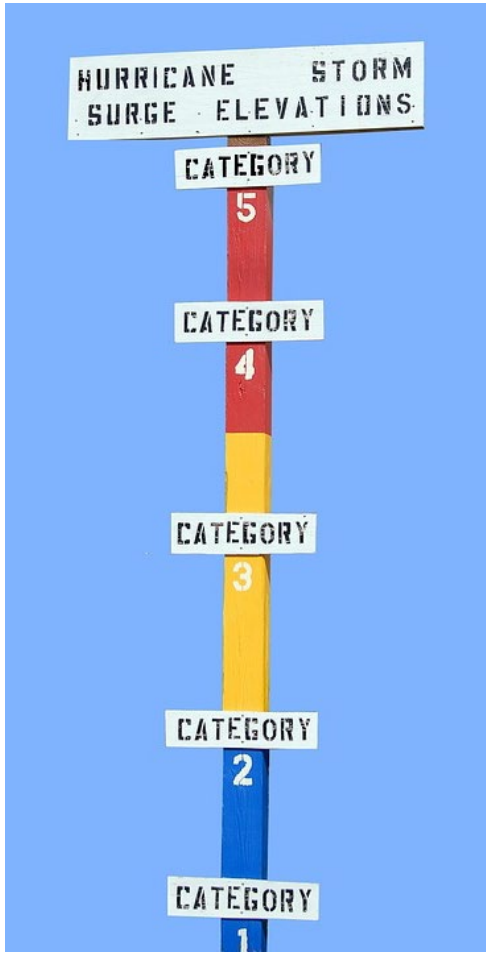
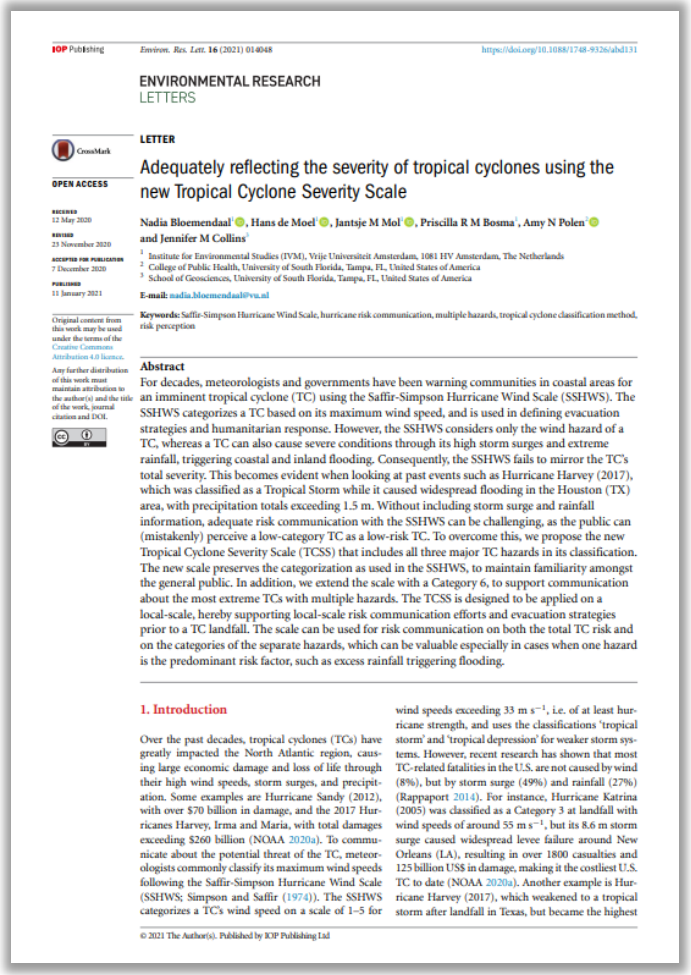
Tropical Cyclone Severity Scale (TCSS)

- One category for all major hazards
- Categories 0 – 5
- Category 6 for most extreme cases





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ENVIRONMENTAL RESEARCH
LETTERS

LETTER

Adequately reflecting the severity of tropical cyclones using the new Tropical Cyclone Severity Scale

Nadia Bloemendaal[1], Hans de Moel[1], Jantsje M Mol[1], Priscilla R M Bosma[1], Amy N Polen[2] and Jennifer M Collins[3]

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Keywords: Saffir-Simpson Hurricane Wind Scale, hurricane risk communication, multiple hazards, tropical cyclone classification method, risk perception

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Tropical Cyclone Severity Scale (TCSS)

- One category for all major hazards
- Categories 0 – 5
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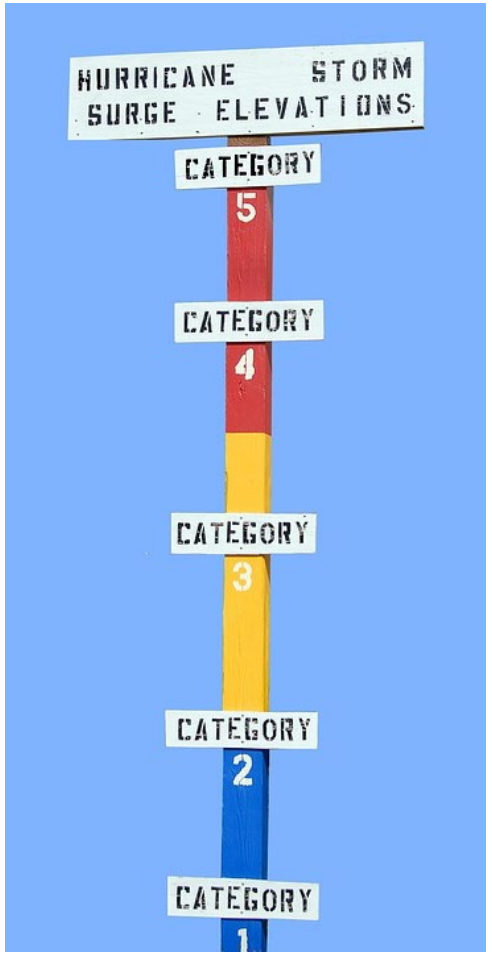
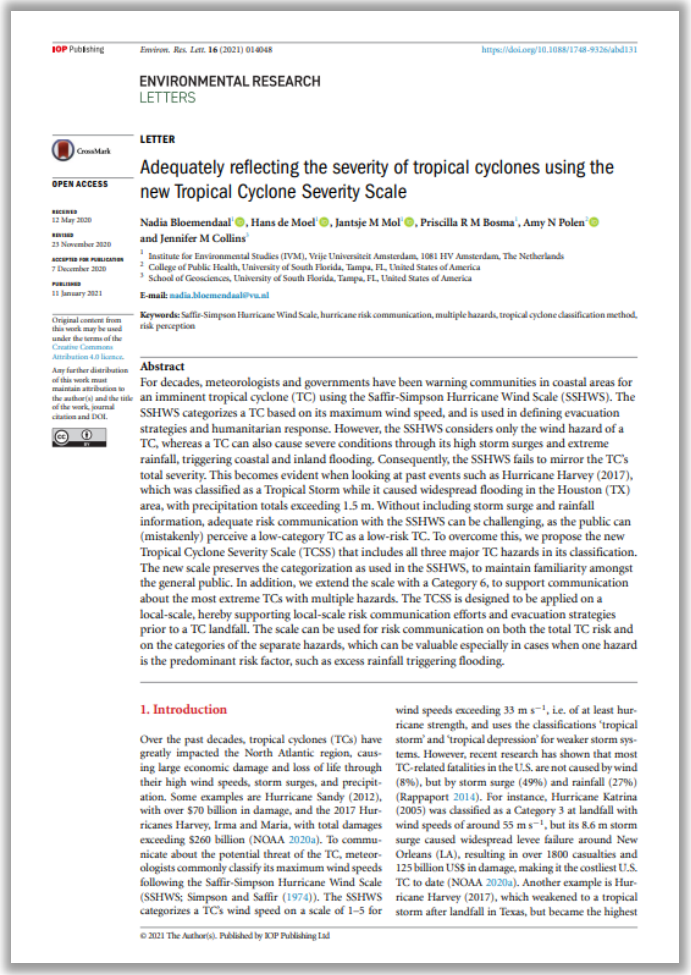
- Pre-landfall predictions
  (for risk communication)





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Tropical Cyclone Severity Scale (TCSS)

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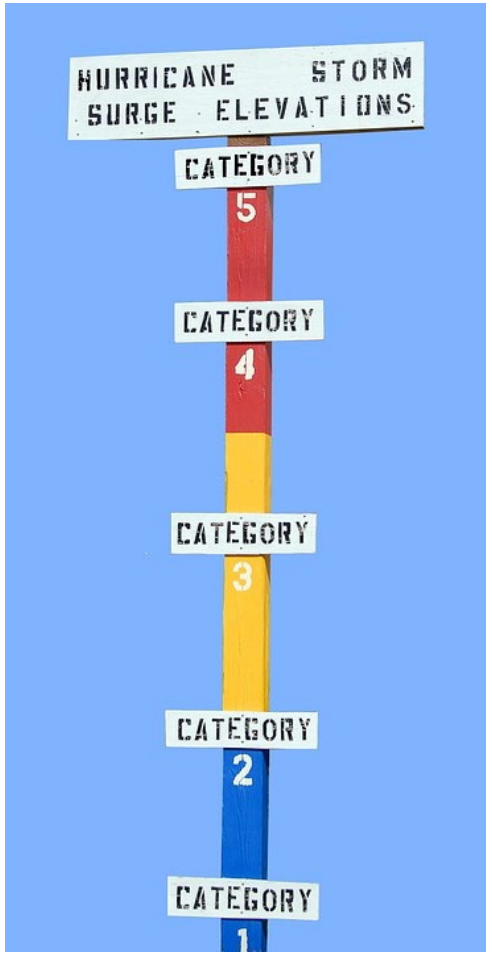
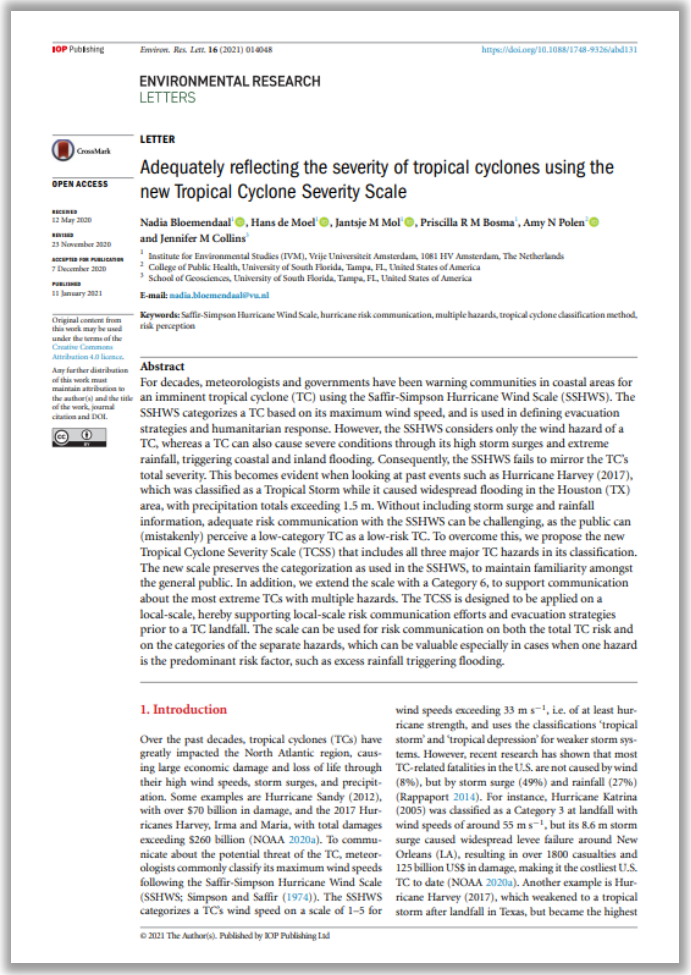
- Categories 0 – 5
- Category 6 for most extreme cases
- Pre-landfall predictions (for risk communication)
- Higher categories for historical high damage events





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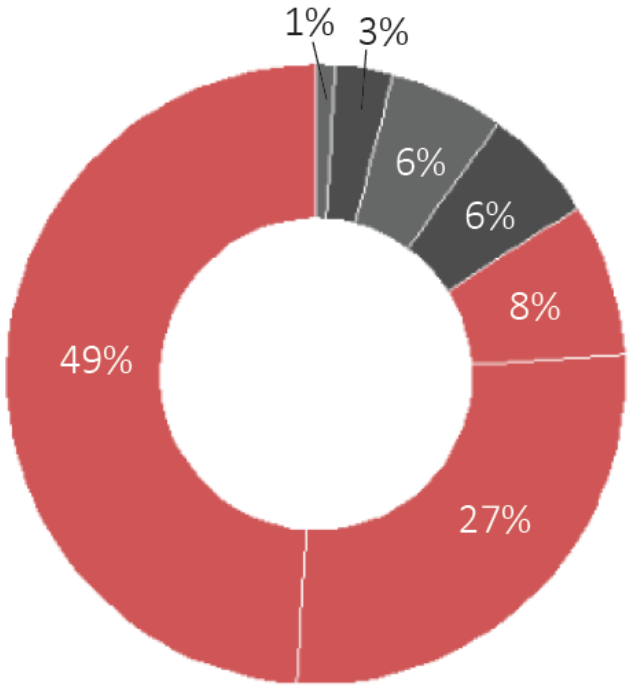


NEW SCALE

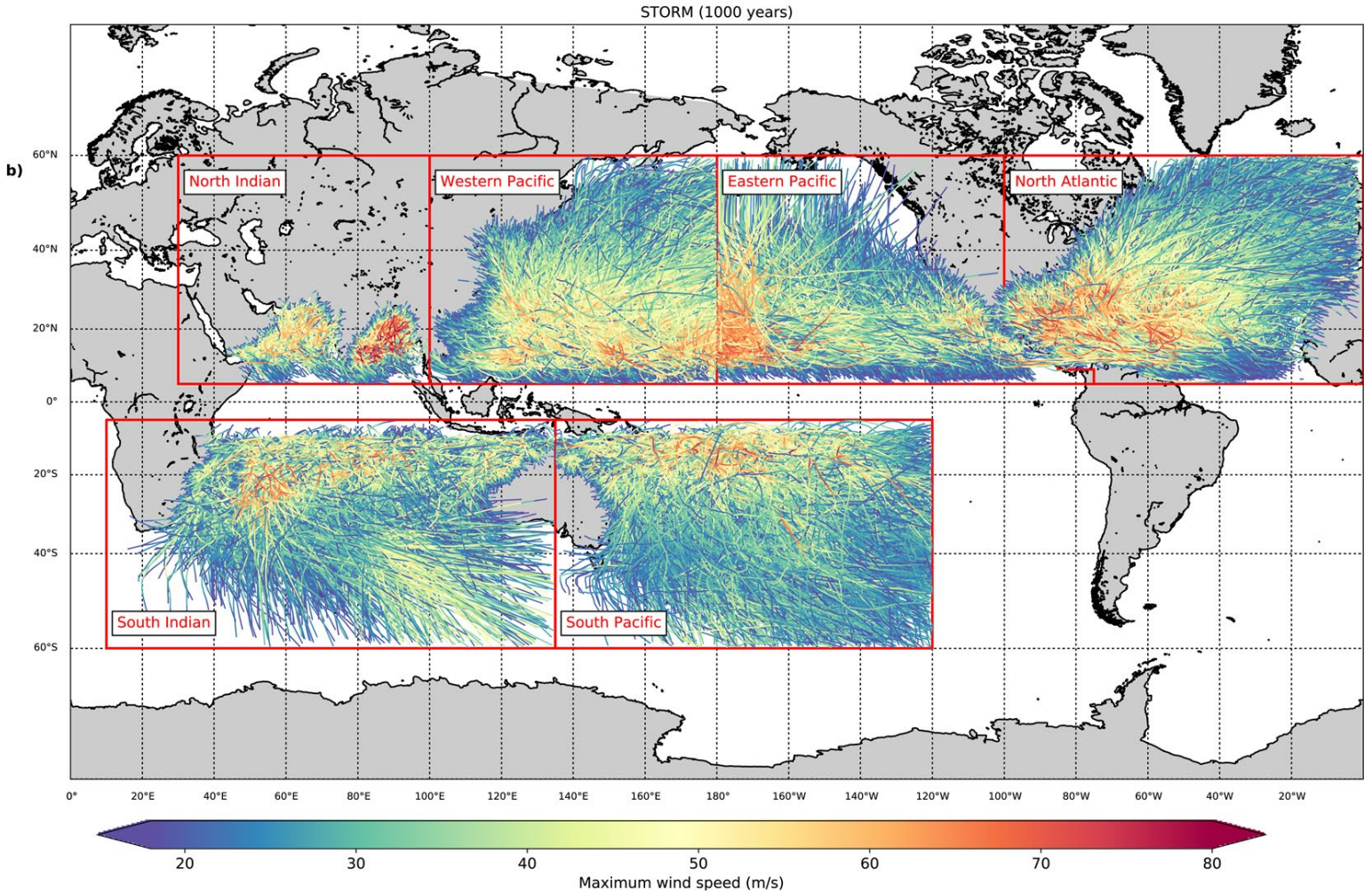
Tropical Cyclone Hazard Scale (TCHS)

based on

wind + **preciptation** + **storm surge**

Bloemendaal, N., Haigh, I. D., de Moel, H., Muis, S., Haarsma, R. J., & Aerts, J. C. (2020). Generation of a global synthetic tropical cyclone hazard dataset using STORM. *Scientific Data*, 7(1), 40.

Using a synthetic storm track



Using a synthetic storm track to build scenarios

Table 1: Overview of scenarios

Name	Wind (mph)	Rain (inches)	Surge (feet)	Category SSWIIS	Category TCSS	Historical example	Main hazard
Chi	130	24	8	3	4	Irma (2017)	Rain
Lambda	74	8	4	0	1	Gordon (2018)	Rain
Omega	108	20	4	2	3	Alex (2010)	Wind
Nu	86	31	10	1	5	Florence (2018)	Rain
Rho	153	8	20	4	5	Emily (2005)	Surge
Sigma	108	8	4	2	2	Bertha (1996)	Wind
Tau	130	8	8	3	3	Fran (1996)	Wind
Phi	130	12	10	3	5	Katrina (2005)	Surge
Theta	164	31	10	5	6	Michael (2018)	All hazards
Psi	130	31	4	3	5	Sally (2020)	Rain

Hurricane Hypothetical

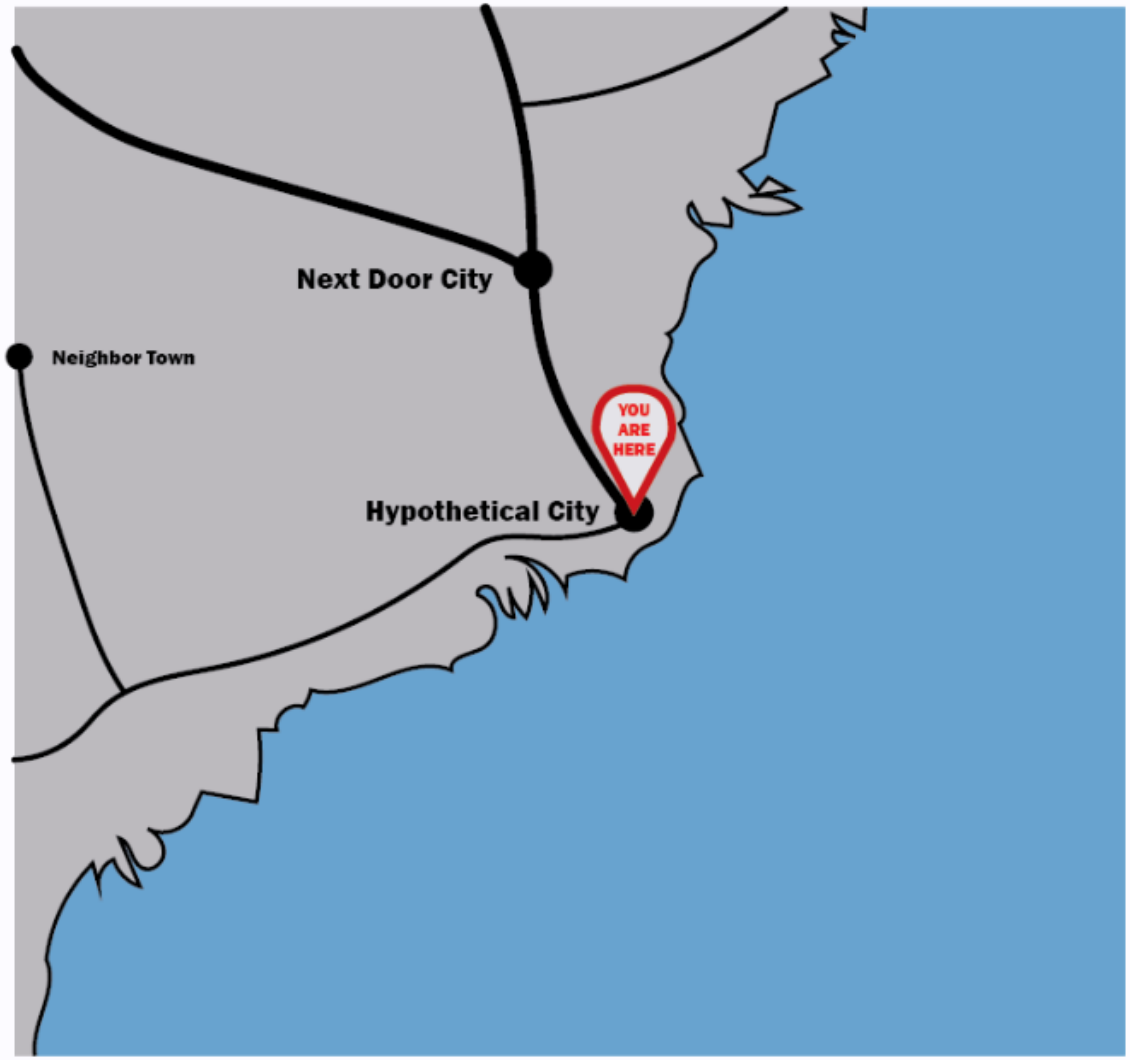
Different on Saffir-Simpson and TCSS

General coastline

Dependent variables:

- Evacuation intent
- Worry
- Precautionary measures

Imagine you live in Hypothetical City (see image below). We will now ask you a couple of questions about a **hypothetical** scenario of an imminent hurricane approaching Hypothetical City. Please answer these questions **as if** you are living in Hypothetical City.



Design

2 × 2 between subjects treatments

- scale: Saffir-Simpson vs. TCSS
- format: graphic vs. text-only

Hurricane Phi expected to make landfall in Home City as a Category 3 storm on Wednesday

Hurricane Omega bringing winds up to 130 mph and 12 inches of rain to Home City region. Storm surge estimates are up to 10 feet. Category 3 on the Saffir-Simpson Hurricane Wind Scale. You can find more information here (Link opens in a new window. Source: Hypothetical Weather Service).

Saffir-Simpson with and without graphic

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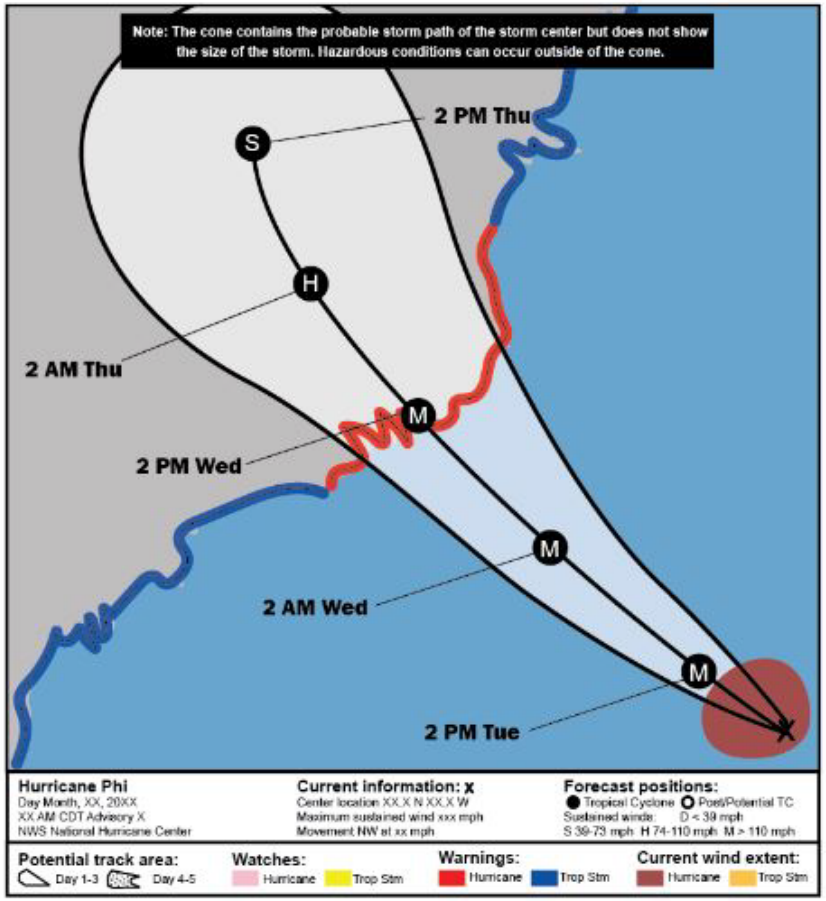

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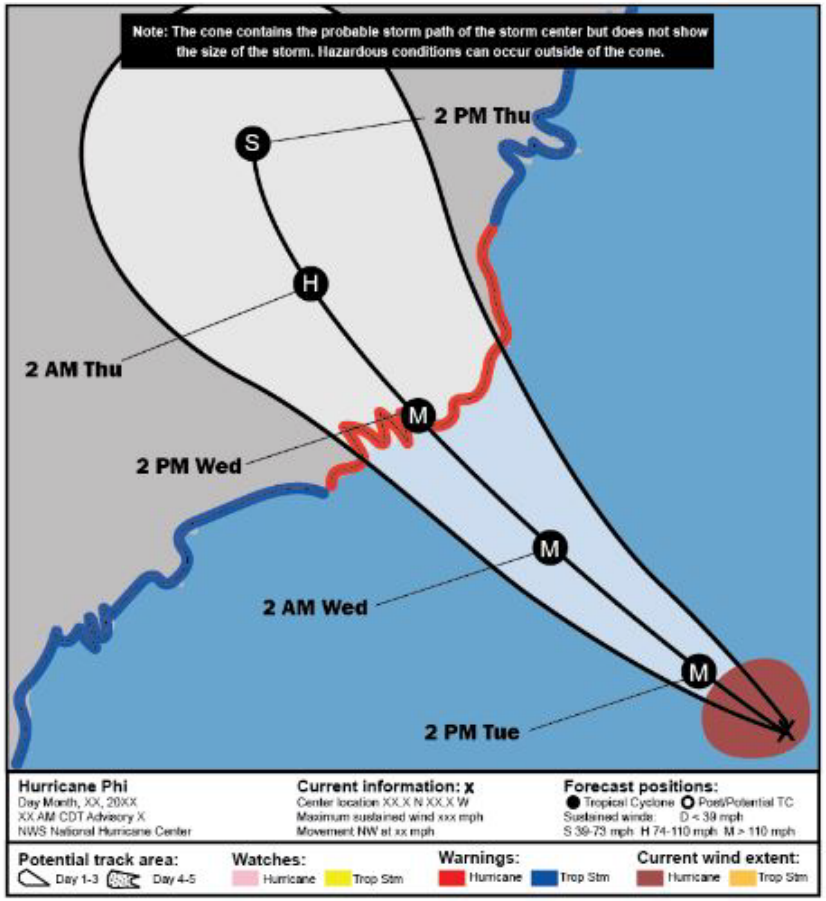

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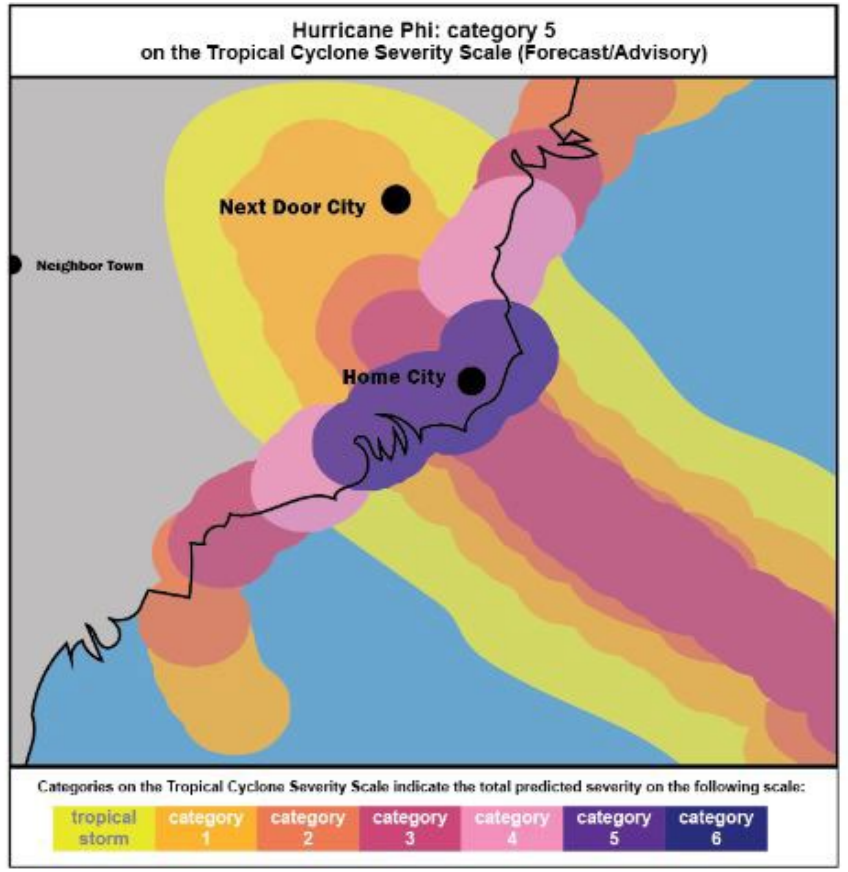
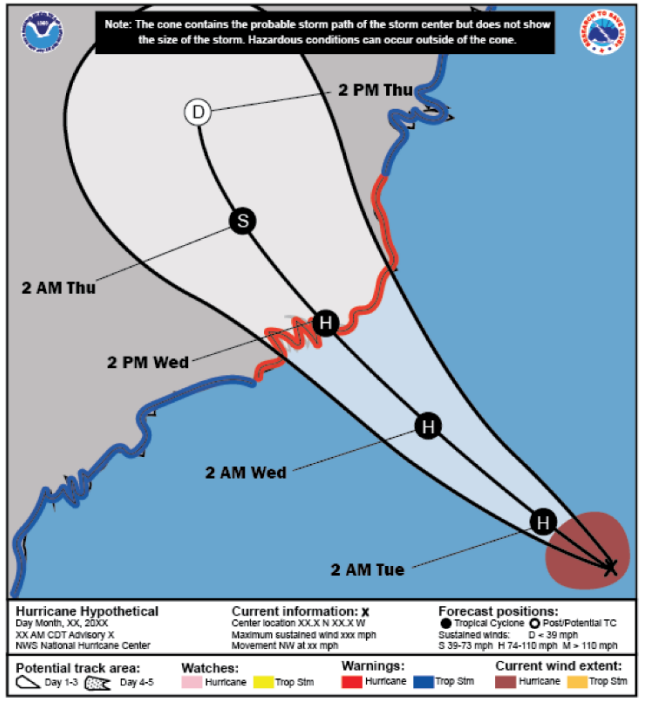


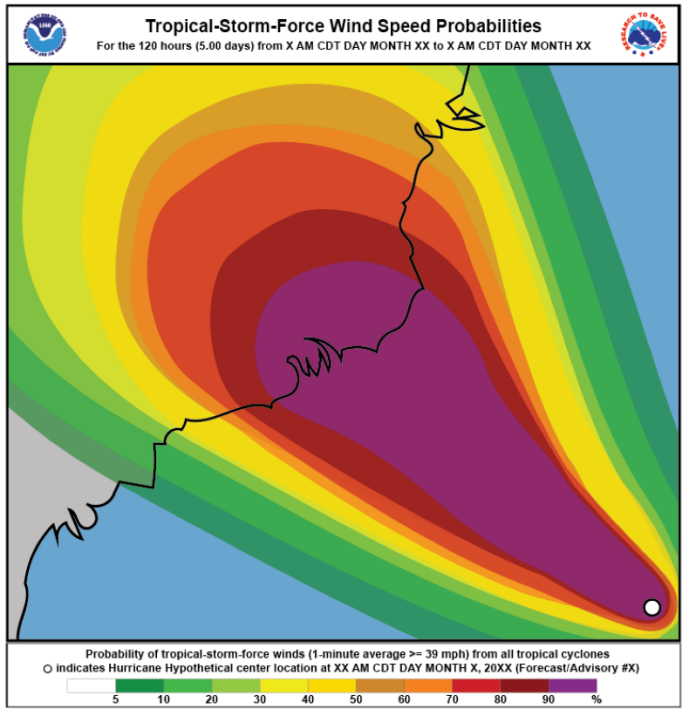
TCSS with and without graphic

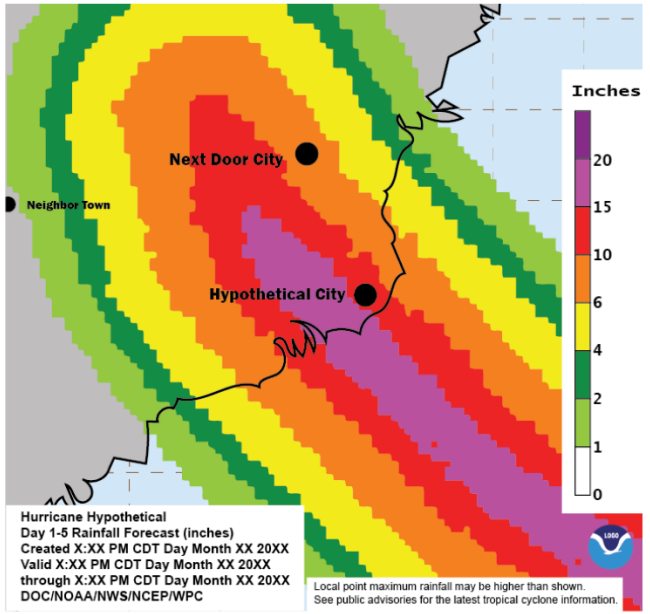
More information

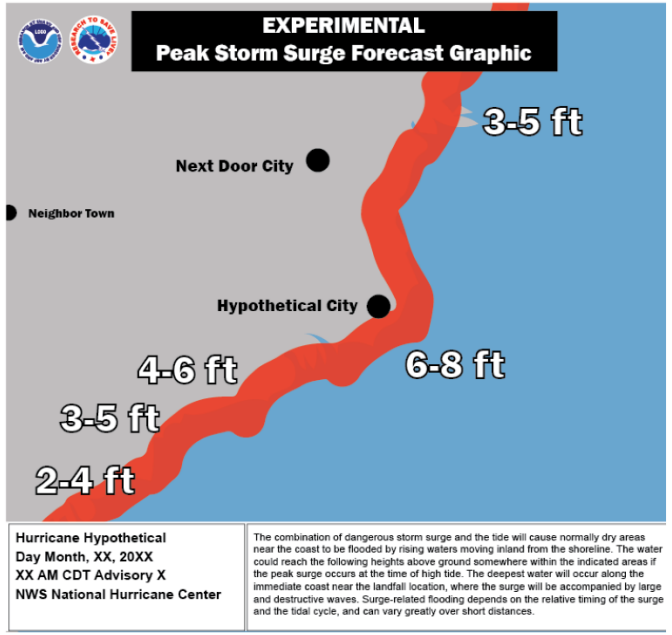
Display of 4 maps in NOAA style

- Cone
- Wind Speed Probabilities
- Rainfall
- Storm Surge









Dependent Variables

- First 5 scenarios
  - Evacuation intent
  - Worry
  - Expected damage
- Last 5 scenarios
  - Quiz questions (e.g. main hazard)

Pilot data (n = 40 on Prolific)

University of Amsterdam
Amsterdam School of Economics

11 July 2023 // Ecological Economics in Tuscany

Experimental Economics for Disaster Preparedness

Jantsje Mol // www.jantsje.nl // @jantsjemol