USENIX'23 Artifact Appendix:
Understand Users' Privacy Perception and Decision of V2X Communication in Connected Autonomous Vehicles

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A   Artifact Appendix

A.1   Abstract

Our understanding of human drivers' privacy perception and decision of V2X communication in connected autonomous vehicles (CAVs) is based on descriptive statistics and inference statistical tests of quantitative data, as well as thematic analysis of qualitative data. We provide the data and explain the analysis methods we used to replicate all results reported in the paper. The artifact includes our collected data (for review only), our quantitative analysis via R code, and the qualitative analysis via excel spreadsheets and Python, such that one can recreate all results in tables, figures, statistical tests, and reported themes throughout the paper.

A.2   Description & Requirements

A.2.1   Artifact check-list (Meta-information)

Data set: Survey responses from the participants (quantitative and qualitative data sets) in our study; non-public.

Run-time environment: We did our analysis on Windows 11 system.

Security, privacy, and ethical concerns: Maintaining the confidentiality of participant data; the dataset will not be publicly available based on the approved IRB protocol.

Metrics: Perceived benefits, perceived risks, willingness to share data, and confidence of sharing decision.

Output: The artifact produces all results, containing tables, figures, and the code counts in users' answers to the open-ended questions.

Experiments: Descriptive statistics, inference statistical tests, and qualitative analysis of responses to the open-ended questions.

How much disk space required (approximately)?: Negligible, less than 1 GB.

How much time is needed to prepare workflow (approximately)?: This depends on whether the required environment (RStudio and PyCharm) and the required packages are already installed. If none of the aforementioned are present, the set-up should take less than 20 min on a modern computer.

How much time is needed to complete experiments (approximately)?: This depends on hardware, but should take less than 30 min on any recent PC or laptop.

Publicly available (explicitly provide evolving version reference)?: All scripts and code are made publicly available[1].

Code licenses (if publicly available)?: The R code and the Python script are licensed under Creative Commons Attribution 4.0 International.

Archived (explicitly provide DOI or stable reference)?: The DOI provided by Zenodo is 10.5281/zenodo.7707330.

A.2.2   Security, privacy, and ethical concerns

All personal identifiable information has been removed from both data sets. There is no risks in executing the analysis. However, we cannot exclude the possibility of those data being used to deanonymize participants. Based on the approved IRB protocol, the data will not be publicly available.

A.2.3   How to access

Along with the supplementary materials, we make all the scripts and code used to analyze data publicly available (see Footnote 1). The artifact includes four main parts: (1) the "CLMM Tests" folder that contains anonymized *Quantitative_Data.csv*, the R script "CLMM_Analysis.Rmd" for data analysis and the expected output "CLMM_Analysis.pdf"; (2) the "Thematic Analysis" folder that contains spreadsheets *Coder1_Coding.xlsx*, *Coder2_Coding.xlsx*, *Final_coding.xlsx*, and the script "Thematic_analysis.py" calculating the inter-rater agreement of the coders and counting the agreed codes. *Code_book.txt* describes the meanings of the codes; and (3) "Supplementary Materials.pdf." Additionally, the "README.md" provides a detailed overview of all files.

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[1] https://zenodo.org/record/7707330#.ZAh0q3bMIQ8

A.2.4 Hardware dependencies

No specific hardware is needed. Our analysis requires less than 1 GB of disk space.

A.2.5 Software dependencies

The quantitative analysis requires R to run. We use RStudio (2022.12.0 Build 353) and R (version 4.2.2). RStudio can be obtained online for free[2]. The following R packages are needed to run the script: `ordinal` and `emmeans`. For the qualitative analysis, the coding results are listed in Microsoft Excel (Version 2301 Build 16.0.16026.20196). We use Python (3.10) and PyCharm (2021.2.3), both of which are publicly available[3]. To calculate inter-rater reliability (i.e., Cohen's Kappa) and count the frequencies of the themes, the following Python packages are needed: `pandas` and `numpy`. Our analysis is done on Windows 11 system.

A.2.6 Benchmarks

Datasets. We use the survey responses collected in our user study. The quantitative analysis (i.e., Cumulative Link Mixed-effects Model (CLMM) analysis) is conducted using the dataset *Quantitative_Data.csv*. The qualitative analysis (i.e., thematic analysis and Cohen's Kappa) is conducted based on *Coder1_Coding.csv*, *Coder2_Coding.csv*, and *Final_Coding.csv*. The description of the codes can be found at *Code_book.txt*.

The quantitative and qualitative data are provided for artifact evaluation only. To maintain participants' privacy, we do not release the data publicly.

Models. We run CLMMs on the *Quantitative_Data.csv* via the "CLMM_Analysis.Rmd."

A.3 Set-up

A.3.1 Installation

Quantitative analysis. Installation time: about 15 min. The quantitative evaluation is performed by using R. The set-up consists of two steps.

Software. RStudio 2022.12.0 Build 353 with R 4.2.2 is recommended because the authors used these versions. R and RStudio are all publicly available and their instructions for version-specific installation can be found at their respective websites.

R packages. When RStudio is installed, it must be started and the analysis script can be opened using the "File" menu. Then the following R packages need to be installed: `ordinal` and `emmeans`. To install these packages using RStudio, open the "Tools" menu and then select "Install packages". In the

search box enter the first package. Then click "Install". Repeat these two steps for the second package. Installation of the packages might take some time if they need to be compiled. Once the two packages are installed, the analysis script can be run. In our experiment, we generate a PDF to view the results, which requires pdflatex. If there is no pdflatex in your computer, you can install the R package `tinytex` in RStudio to meet this requirement using the same method described above.

Qualitative analysis. Installation time: about 5 min. Same as the quantitative analysis, the set-up consists of two steps.

Software. Python (3.10) and PyCharm (2021.2.3) are both publicly available and their instructions for version-specific installation can be found at their respective websites.

Python packages. To run the `.py` script for thematic analysis, the following dependencies also need to be installed: `pandas` and `numpy`. You can install them one by one from the terminal using pip (which is automatically installed with Python). In PyCharm, the packages can also be installed directly through "Python Packages" tool bar at the bottom-left corner.

A.3.2 Basic test

After installing the dependencies (the R packages and the Python packages), you can run "Basic_Test.R" and "Basic_Test.py" to see whether the required dependencies can be loaded, respectively. There should not be any error messages if the packages are successfully installed.

A.4 Evaluation Workflow

A.4.1 Major claims

The major claims made in the paper are as follows:

(C1): While participants perceived more benefits but fewer risks in the three driving-related scenarios, they perceived more risks but fewer benefits in the infotainment scenarios (**RQ1**). This is proven by **E1**. Statistical inference test results are described in **Section 4.1** and **Table 3**. The descriptive statistics are illustrated in **Figure 2 (a)** and **(b)**.

(C2): Only the privacy priming was effective in reducing participants' perceived benefits than those in the control. Instead of augmenting their privacy concerns, the privacy&security priming condition showed similar results as those in the control (**RQ2**). This is proven by **E1**. Statistical inference test results are described in **Section 4.1** and **Table 3**. The descriptive statistics are illustrated in **Figure 2 (a)** and **(b)**.

(C3): Participants made more liberal privacy decisions in the driving-related scenarios, which could have been caused by perceiving both more benefits and fewer risks (**RQ1**). Moreover, they made more conservative privacy decisions as long as they were primed (**RQ2**). This is proven

by **E1**. Statistical inference test results are described in **Section 4.2** and **Table 3**. The descriptive statistics are illustrated in **Figure 2 (c)**.

(C4): We observed a non-significant trend that participants with much experience in driving assistance and connectivity functions perceived more benefits and more risks of data sharing. Moreover, there was a non-significant trend that they showed higher willingness in sharing the data (**RQ3**). This is proven by **E1**. Statistical inference test results are described in **Section 4.3** and **Table 3**. The descriptive statistics are illustrated in **Figure 3**.

(C5): Our thematic analysis verified the privacy-safety trade-off. The analysis revealed not only common factors similar to other settings, but also some unique factors for the CAV context (**RQ1**). This is proven by **E2**. Inter-rater agreement via Cohen's Kappa and thematic analysis results are described in **Section 4.5**.

A.4.2 Experiments

(E1): Quantitative analysis

Execution Time: about 15 min. The results from **Sections 4.1** to **4.3**, **Table 3**, **Figures 2** and **3** are produced in the R code via the following steps:

1. Open the RStudio.

2. In RStudio, open the document "CLMM_Analysis.Rmd" by clicking "File", then "Open File...", and selecting "CLMM_Analysis.Rmd".

3. Then click the drop-down arrow of "Knit" and select "Knit to PDF".

4. Once completed, you may view the produced PDF: "CLMM_Analysis.pdf".

The generated PDF will include results verifying claims 1-4 (**C1**-**C4**) (i.e., **Findings 1-4** in the paper).

(E2): Qualitative analysis

Execution Time: about 1 min. Cohen's Kappa (inter-rater reliability) with the initial codes of two coders and the frequencies of each theme with the final codes from **Section 4.5** are produced in the Python code via the following steps:

1. Open the PyCharm.

2. In PyCharm, click "File", then "Open...", and select the folder where "Thematic_Analysis.py" is located.

3. Then click "Run" and select "Run...". In the pop-up window, select "Thematic_Analysis" to run it.

Once completed, you will see the output results (should be the same with "Thematic_Analysis.pdf"). The generated results will verify claim 5 (**C5**) (i.e., **Finding 5** in the paper).

A.5 Notes on Reusability

Our artifact (R and Python scripts) can be reused to analyze other human-subject studies' results using CLMM, Cohen's Kappa, and thematic analysis.

A.6 Version

Based on the LaTeX template for Artifact Evaluation V20220926.