Designing Privacy-Conscious Consent Interfaces: A User Study of Account Aggregator Onboarding Flows

SURYA GANESH, AMAN PRIYANSHU, and JINGXIN SHI, Carnegie Mellon University, USA

PROJECT ADVISORS: DR. SARAH SCHEFFLER and DR. OMER AKGUL, Carnegie Mellon University, USA

This paper examines privacy consent mechanisms for financial data sharing, with a focus on Account Aggregator onboarding processes. Drawing from existing research and industry practices in privacy consent mechanisms, we created a pool of research-informed UI variations of privacy notices and privacy choice interfaces. Through user studies involving 264 participants, we evaluated a selected subset of these variations: six distinct information presentation interfaces and four consent option interfaces. The study combined quantitative metrics (statistical analysis using Chi-Square tests and Spearman correlations), technical measurements (interaction logging within the application), and qualitative insights (thematic coding of user feedback) to assess interface effectiveness. We provide actionable recommendations for implementing privacy-conscious interfaces in open finance systems. We establish a replicable approach for evaluating privacy consent mechanisms across different domains.

1 Introduction

Privacy consent interfaces help users understand and control how their data is used across different domains. Consent interfaces share common design elements across different domains, but their effectiveness depends heavily on the specific context and user needs they serve. Design and evaluation of interfaces require careful consideration of domain requirements, user expectations, and implementation constraints.

This project, initiated in collaboration with Silence Laboratories focuses on, **privacy consent interfaces in open finance, specifically the onboarding flows for account aggregators.**

These onboarding flows guide users through the process of connecting their financial accounts, ensuring they fully understand how their data will be used, shared, and protected. By providing clear consent mechanisms, account aggregators help users maintain control over their financial information while facilitating comprehensive financial management.

Authors' Contact Information: Surya Ganesh, sayyampe@andrew.cmu.edu; Aman Priyanshu, apriyans@andrew.cmu.edu; Jingxin Shi, jingxins@andrew.cmu.edu, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA; **Project Advisors:** Dr. Sarah Scheffler; Dr. Omer Akgul, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA.

Account aggregators are platforms that enable users to securely link and manage multiple financial accounts from various institutions in one place.

Open finance enables users to share their financial data across institutions through standardized interfaces. This is in contrast to traditional banking systems, where data remains isolated within each institution. Account aggregators serve as intermediaries in this ecosystem, helping users consolidate and manage their financial information from multiple sources. Unlike conventional financial dashboards that only display data from a single institution, aggregators provide unified access across multiple financial services.

Open finance is gaining significant traction globally, enabling unprecedented data sharing between financial institutions and transforming how users manage their financial lives. This paradigm shift allows consumers to leverage their financial data across multiple services, creating opportunities for more personalized and comprehensive financial management. Account aggregators have emerged as crucial intermediaries in this ecosystem, helping users consolidate and control their scattered financial information while ensuring secure data transmission between institutions. However, as these services proliferate, the critical aspect of privacy consent management has often been overlooked, particularly in terms of how users understand and control their data sharing permissions.

Our work evaluates interface variations for privacy consent in account aggregator onboarding flows. We aggregated existing research in privacy consent interfaces, notices, and design patterns across different domains, building a pool of established approaches to privacy communication and user choice. From these, we selected and tested a subset of design variations, implementing six information presentation interfaces and four consent option interfaces, each addressing specific aspects of the onboarding process. While focused on account aggregator implementations, this evaluation approach could inform interface design in related contexts. Our experiments and user study examine these interfaces within Silence Laboratories' account aggregator onboarding flow, where privacy-enhancing technologies shape the consent requirements.

1.1 Sponsor Background: Silence Laboratories

Silence Laboratories is a startup focused on privacy technology. Silence Laboratories develops privacy-enhancing technologies (PETs) across several domains, including healthcare, advertising, and financial services. In open finance, they aim to work with account aggregators to enable secure data sharing between financial institutions. Their account aggregator implementation uses PETs to protect user data during sharing, providing an opportunity to enhance existing privacy consent interfaces in open finance onboarding flows.

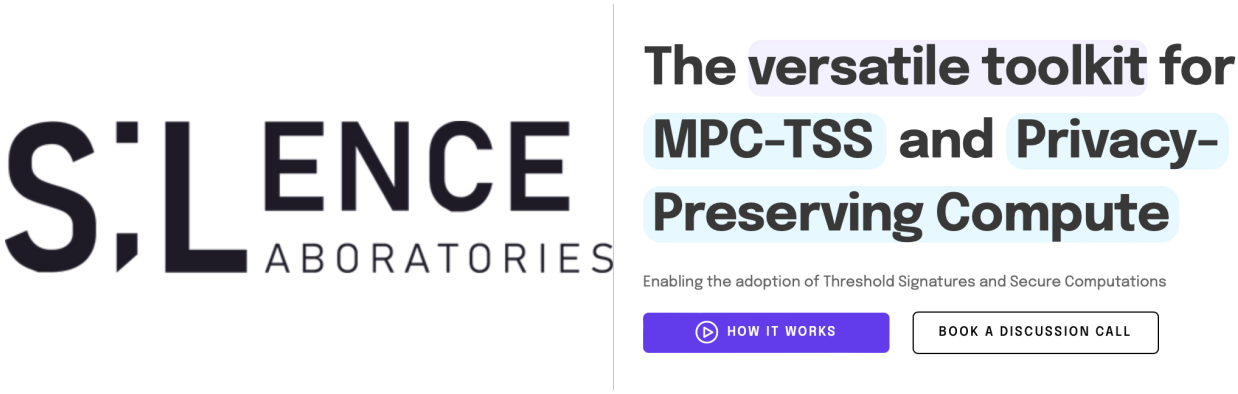


Fig. 1. Silence Laboratories is a cybersecurity company specializing in decentralized multi-factor authentication and privacy-preserving computations, utilizing advanced cryptographic techniques.

Our work with Silence Laboratories aims to explore privacy interface design during account aggregator onboarding of the user. Where Silence Laboratories cryptographic privacy and auditability platform [26] enables data processors and aggregators to cryptographically prove that only consented data is being processed by the data processors after obtaining consent. Silence Laboratories have built a multi-party computation framework that can act between the data processor, data aggregator and the user. This enables a data processor to get the underlying inference, without having to transfer the actual data to the data processor. Each Inference is tied to a specific consent provided by the user using a cryptographic mechanism as mentioned in [26].

We will study how users interact with privacy choices during setup, particularly when encountering explanations of PETs-enabled data sharing. The evaluation will cover different approaches to presenting privacy information and consent options, working within practical implementation constraints. These observations aim to help inform the design of privacy consent interfaces where PETs add technical complexity to user choices.

1.2 Research Goals and Questions

The integration of PETs in account aggregator flows presents specific challenges for privacy consent interface design. While these technologies enhance data protection, they also introduce additional complexity that users must understand during the consent process. Interface design in this context requires balancing technical accuracy with user comprehension, particularly when explaining PETs-enabled data sharing protections. Our work aims to address key challenges in account aggregator onboarding, including user confusion caused by overly technical explanations, information overload, and insufficient clarity on data sharing permissions. By evaluating how

different interface elements impact user engagement and comprehension, we aim to identify privacy consent mechanisms that are both user-friendly and effective in ensuring informed consent.

Our study will test specific variations in how privacy information and consent options are presented to users. We implemented and evaluated interfaces that differ in their approach to explaining data sharing permissions and PETs protections. These variations explore different ways of structuring privacy information and consent choices, while maintaining the constraints of a practical onboarding flow. Through this evaluation, we aim to understand how interface design choices affect user comprehension and engagement during initial setup.

To address the challenges of integrating PETs in account aggregator consent flows, our research examines three key research questions:

(1) **RQ1:** How can consent mechanisms balance granular control and user fatigue in financial data sharing contexts?
(2) **RQ2:** What UI elements effectively communicate data usage terms and privacy guarantees?
(3) **RQ3:** How can consent-bound computation be conveyed clearly to users?
(4) **RQ4:** How can we ensure that the choices made by the user are conscious and aware.
(5) **RQ5:** How can we Communicate Data Custodianship and Collaborative Use to the users effectively?

2 Prior Work and Literature Review

Privacy consent interfaces adapt to changes in digital services and data sharing practices. Studies examining privacy policies and user interaction have focused on readability, visual presentation, and trust development through various analytical frameworks [10–12]. The financial domain presents specific considerations for privacy interfaces due to the nature of financial data sharing [4, 9].

Prior research has examined how users engage with privacy notices in digital services. Studies indicate relationships between policy comprehension and user trust, though findings vary across different presentation methods and contexts [18]. Financial services introduce additional factors in privacy communication, particularly regarding data sharing across institutions.

2.1 Privacy Policies and Comprehension

Analysis of financial privacy policies reveals that many require college-level reading comprehension [4]. Similar readability challenges exist across privacy notices in other domains [8, 16, 22, 23]. Studies examining general privacy notice comprehension found that perceived understanding influenced users' willingness to engage with privacy information [18].

Layered notices, which present a short one-screen overview with standardized headings linking to full privacy policies, were introduced in the mid-2000s by [17]. Several major companies including Microsoft and IBM implemented this approach, and European privacy regulators endorsed the concept based on research suggesting improved policy design could increase readership [1–3]. However, comparative studies found that while users read layered formats more quickly, the effectiveness of this approach showed mixed results [17]. As the accuracy for different questions varied widely, for example 91% of participants answered correctly when asked about cookies. But, only 46% answered correctly regarding telemarketing.

2.2 Visual Design Approaches

Visual design principles have been examined in domains such as contract presentation. Studies suggest that visual formats can support document accessibility and comprehension [19, 20], leading to exploration in the context of privacy. Early experiments with expandable grid presentations for privacy policies showed modest advantages for information navigation by the user [21].

Later research exploring visual elements specifically in privacy notices yielded mixed results. Studies testing privacy policy visualizations found that while basic visual structure helped, complex visual elements such as security icons showed limited benefits and in some cases decreased perceived trust [6]. These findings highlighted the challenges in translating visual design principles to privacy communication, something we could study.

2.3 Trust Development Through Interface Design

Research has identified connections between interface design and user trust development. Early work examining online trust found that privacy concerns influenced technology adoption [14]. Studies in cloud computing contexts also suggested roles for transparent communication of applied privacy and security in trust building [15].

Contract visualization research provides additional perspectives on trust development through interface design. Studies indicate that efforts to make agreements more understandable through visualization can positively influence trust perceptions [7]. These findings suggest potential applications for privacy interface design, though direct evidence remains limited.

The examined studies reveal patterns in how users interact with privacy information and how different presentation approaches affect comprehension. Work on layered and visual presentations shows both benefits and limitations, while trust research highlights roles for clear communication.

Available research focuses primarily on general privacy notices, with limited examination of financial context specifics. The small number of studies directly examining financial privacy interfaces leaves questions about how findings from general privacy notice research apply in financial settings. Additionally, most studies examine traditional privacy notices rather than modern data sharing scenarios such as in the case of Silence Laboratories encryption product [26].

3 Methodology

Our data collection includes both quantitative metrics from interaction logs and survey responses, and qualitative feedback from open-ended survey questions to understand how participants engage with privacy consent interfaces during account aggregator onboarding.

The study examines how users interact with privacy choices during account aggregator onboarding. By recording metrics — time spent on different interface elements, post-interaction survey responses, and responses to open-ended questions, we gather concrete data about how design variations influence user engagement with privacy consent interfaces. The qualitative feedback was analyzed using thematic analysis, with detailed codebooks provided in the appendix, while comprehensive statistical analysis procedures and results are presented in the subsequent Results & Analysis section.

3.1 UI Design Framework

We developed interface variants to test different approaches to privacy notice presentation. A variant in our context refers to a specific version of the interface that changes a design element with respect to the others. This controlled variation allows us to study how specific design choices affect user comprehension and interaction. Drawing from our literature review in Section 2, we identified two main areas for interface variation: how information is presented to users and how interface options are structured.

Now for our study, **information presentation** refers to how privacy details and data sharing terms are displayed to users. This includes choices like using technical versus simplified language, adding visual elements like icons, or organizing information in layers versus showing it all at once. These presentation choices aim to affect how easily users can understand and retain privacy information during the consent process.

Interface options, on the other hand, address how users make and review their privacy choices. This includes decisions such as showing all consent options on a single page versus spreading them across multiple screens, or varying how detailed the explanations are for each option. These structural choices can impact how thoroughly users consider their privacy decisions and how confident they feel in their choices.

Based on these two areas of variation, we identified and developed multiple design variants, selecting a focused subset for detailed evaluation according to implementation feasibility and study scope considerations. These variants allow us to examine specific aspects of interface design - for instance, how technical language affects comprehension or how breaking information into layers impacts user engagement. Each variant aims to test particular ideas about user interaction while

maintaining consistent core functionality. This section details the design choices and rationale behind each variant type.

3.1.1 Information Presentation Approaches. The baseline approach establishes two fundamental variants: technical and non-technical privacy notice presentations. The technical variant, following McDonald et al.'s structured format study, presents comprehensive details with precise terminology to establish an information retention baseline [17]. Its non-technical counterpart maintains similar comprehensiveness while employing simplified language, allowing us to evaluate the impact of technical complexity on user comprehension.

Building upon these baselines, we incorporated highlighted variations of both technical and non-technical presentations. This design choice was informed by Wilson et al.'s findings that highlighted paragraphs significantly improved annotation accuracy and user confidence, with up to 42% of users reporting improved ease of understanding compared to non-highlighted versions [25]. The highlighting strategy emphasizes key privacy terms and implications through strategic use of color while maintaining the underlying content structure.

We further explored the icon-text combined approach, though research by Stransky et al. suggests limited additional benefits from security icons, with some studies noting potential negative effects on perceived trust [24]. Despite these findings, we included this variant to examine its effectiveness specifically in financial data sharing contexts, where visual aids might serve different purposes than in general security communications.

The layered information approach emerged as a particularly promising variant based on McDonald et al.'s research, which demonstrated improved comprehension speeds and significantly higher ease-of-understanding scores (M=4.8) compared to natural language formats (M=4.4) [17]. This approach presents information in progressive levels of detail, allowing users to navigate complexity according to their needs and interests.

3.1.2 Unused Information Presentation Approaches. A visualization-based approach was also considered, supported by Becker et al.'s findings showing increased user trust and perceived ability when privacy policies incorporated visual elements [5]. Their research demonstrated a notable effect on perceived ability (mean difference of 0.42, d=0.34, p-value 0.093), with users reporting higher confidence in visualization conditions. Similarly, Hagan's work on user-centered privacy communication design provided additional support for visual representation of privacy concepts [13]. However, this variant was ultimately excluded from our final implementation due to the complexity of accurately representing financial data sharing processes through visualizations while maintaining consistency across test conditions.

We also explored an analogy-based approach that would explain privacy concepts through real-world comparisons, aiming to leverage users' existing mental models to enhance understanding

of complex privacy mechanisms. While this approach showed intuitive promise for explaining technical concepts to non-technical users, we found insufficient empirical evidence in privacy notice literature to support its inclusion in our final framework.

3.1.3 Interface Design Patterns. The interface design patterns focus on how users interact with data sharing choices and permission settings, examining different approaches to organizing and presenting these selection options. These patterns explore various methods of structuring user decision-making in privacy consent interfaces [17]. The implemented patterns include:

(1) **Single-Page**: A single-page comprehensive view where all data sharing options and their implications are immediately visible and selectable. This pattern allows users to see the complete scope of their choices at once, enabling direct comparison of different permission options.
(2) **Multi-View**: Content distributed across sequential pages, where related data sharing choices are grouped together and presented step-by-step. This pattern breaks down the decision-making process into smaller, focused segments.

Our initial design exploration included additional patterns such as icon-enhanced variants and a collapsed read-more structure. The icon-enhanced variations were excluded as these visual elements were already being evaluated in the information presentation approaches. The selected patterns provide a focused framework for examining how the structure of choice presentation affects user decision-making and engagement with privacy options. An additional dimension of variation was implemented within the option text itself, where we examined both technical and high-level descriptions of data sharing choices to understand how the complexity of option descriptions influences user comprehension and decision-making.

We summarize this subsection 3.1 by detailing the variations studied by us in tables 1 - 3. Table 1 summarizes the privacy notice variations examined in this study, detailing their implementation approaches and underlying design rationales. Table 2 presents the text variations explored within the option interface, while Table 3 outlines the structural design patterns implemented for option presentation. Together, these variations create a comprehensive framework for evaluating different aspects of privacy consent interfaces in financial data sharing contexts.

Also, we assume the effects of information presentation (Page 1 of the consent interface) and consent option presentation (Page 2 of the consent interface) are independent, allowing us to analyze these interface variations separately without considering interaction effects between them.

3.2 User Study Design

We conducted a between-subjects study with 264 participants to evaluate the effectiveness of different privacy consent interface designs in account aggregator onboarding flows. Participants

Table 1. Privacy Information Presentation Variants

Variant	Implementation Approach	Design Rationale
Baseline (Technical)	Comprehensive technical details with precise terminology	Establishes baseline for information retention with full technical disclosure [17]
Baseline (Non-Technical)	Comprehensive details with simplified language	Provides easy to read disclosure [17]
Highlighted (Technical)	Key technical terms and privacy segments emphasized through styling	Enhances visibility of critical segments of the notice [25]
Highlighted (Non-Technical)	Key simplified terms and privacy segments emphasized through styling with simplified language	Aims to grab attention while being easy to read [25]
Icon + Text Combined	Visual icons paired with explanatory text	Explores impact of visual aids on understanding and trust [5]
Layered Information	Progressive levels of detail presentation	Manages information complexity through structured disclosure [17]

Table 2. Consent Option Text Variations

Variant	Implementation Approach	Design Rationale
Technical	Detailed technical specifications	Provides complete technical transparency
High Level	Simplified explanations	Focuses on general understanding

Table 3. Consent Option Design Variations

Pattern	Implementation Approach	Design Rationale
Single-Page	Single-page comprehensive view	Enables direct comparison of options
Multi-View	Sequential page organization	Breaks down decision-making process

were randomly assigned to one of six information presentation variants and one of four consent option variants, allowing us to assess both comprehension and interaction patterns across different interface approaches. Our user study employed a structured approach to participant recruitment and data collection, designed to gather comprehensive insights into user interaction with privacy consent interfaces. The study protocol was developed to ensure interaction data collection in examining user behavior around financial data sharing decisions.

This study was reviewed and approved by Carnegie Mellon University's Institutional Review Board (IRB). The study was designed as minimal risk research, with participants only interacting with interface prototypes and providing feedback through surveys. All participants were informed about the study's purpose, procedures, and their rights before participation. Data collection focused

on interface interactions and survey responses, with no sensitive personal information gathered. Participation was voluntary, and participants could withdraw at any time. Compensation was set at $15 per hour, based on the estimated completion time of 13-15 minutes.

3.2.1 Participant Recruitment. The study targeted individuals aged 18 and above who actively engage with digital financial services, ensuring participants had relevant experience with privacy decision-making in financial contexts. Recruitment focused on achieving diverse representation.

Participant recruitment was conducted through Prolific, an online research platform, with participation restricted to U.S. residents to ensure familiarity with relevant privacy regulations.

3.2.2 Survey Implementation and Structure. The study was implemented using Qualtrics for survey administration, complemented by custom JavaScript implementations for interaction tracking. The survey framework was structured into five distinct sections, each serving specific research objectives:

(1) **Section A: Consent and Screening**
   - Obtained informed consent from participants

(2) **Section B: Scenario Presentation** A.2
   - Introduced participants to a realistic Account Aggregator onboarding scenario
   - Provided context for subsequent interface interactions
   - Established the clear onboarding objective for participants

(3) **Section C: Interface Interaction**
   - Presented participants with one end-to-end app variant (one for Information Presentation and one for Consent Option)
   - Allowed natural interaction with the consent interface
   - Recorded detailed interaction metrics through client-side logging

(4) **Section D: Post-Interaction Questions**
   - Gathered immediate feedback on interface usability
   - Assessed comprehension of privacy implications
   - Collected both structured and open-ended responses

(5) **Section E: Demographic Information**
   - Collected relevant demographic data
   - Gathered information about participants' technical background
   - Assessed general privacy attitudes and behaviors

3.2.3 Data Collection Methodology. The study implemented a dual-axis data collection approach, gathering both explicit user feedback and implicit interaction data. This comprehensive data collection strategy enabled analysis of both stated preferences and actual behavior patterns:

Survey Response Data:

- Likert scale responses measuring user satisfaction, comprehension, and confidence
- Multiple-choice questions assessing understanding of privacy implications
- Open-ended responses capturing qualitative insights and suggestions
- Demographic information and privacy attitude indicators

Interaction Data:

- Time spent on different interface elements
- Navigation patterns through multi-view interfaces
- Interaction sequences with various UI components
- Selection and deselection patterns for privacy options

The interaction data was collected through client-side JavaScript implementations that monitored user behavior without impacting the natural flow of interaction. This data was accumulated locally and transmitted as a consolidated blob to our endpoint upon survey completion.

To mitigate potential order effects and survey fatigue, question sequences within each section were randomized. This randomization strategy helped ensure that response patterns were not systematically influenced by question order or participant fatigue.

3.3 Analysis Framework

Our analysis framework expands on the research questions introduced earlier, detailing specific metrics and evaluation approaches for each area of investigation:

(1) **How can consent mechanisms balance granular control and user fatigue in financial data sharing contexts?**
This question explores how giving users more detailed control over their data sharing preferences affects their ability to engage with the interface. When users have many granular options does it lead to potentially less thoughtful decision-making? At what stage of option-presentation does the user feel overwhelmed? We aim to answer this research question by addressing such issues. We examine this through several measurements: Likert scale questions about feeling overwhelmed, interaction logs tracking time spent across variants, and open-ended questions about which interface elements felt tedious or difficult to process.
For the first research question, we examine this through specific survey questions aiming to understand user experience. We ask "How easy was it to customize your data sharing preferences within the interface?" (Very Easy to Very Difficult) and "At any point, did you feel overwhelmed by the amount of information or the number of choices presented?" (Yes, Somewhat, No). These questions aim to understand how users handle the amount of choices

and information presented. We use interaction logs to track time spent on customization options in seconds. We analyzed differences between interface variants using Chi-Square tests, which are appropriate for our categorical survey responses. These questions alongside statistical metrics help us examine if more detailed privacy controls affect user engagement.

(2) **What UI elements effectively communicate data usage terms and privacy guarantees?**

When users grant permissions for data sharing, they need to understand what they're allowing and what protections are in place. Different UI elements like icons, highlighted text, or layered information might help or hinder this understanding. We assess this through multiple-choice questions testing recall of key privacy terms mentioned in the notice page, Likert scale ratings of perceived clarity for different UI elements, and open-ended feedback about which interface components helped users understand better.

For the second research question, we aim to measure data usage understanding through three survey questions. We ask "How would you rate the clarity of the information presented about how your data will be used?" (Very Clear to Very Unclear). To assess information retention, we include "Based on the consent interface, what types of data will Silence Laboratories access to provide its services? (Select all that apply)" and "For what specific purposes has Silence Laboratories requested to use your Personally Identifiable Information? (Select all that apply)." We aim to analyze differences between interface variants using Chi-Square tests for both first-page styles and second-page styles. We also track user's actual selection through interaction logging UI and compare them with their survey responses to compute recall. These responses help us evaluate which interface elements work better for communicating privacy information.

(3) **How can consent-bound computation be conveyed clearly to users?**

Privacy-preserving technologies add technical complexity to data sharing explanations. This question examines how to present these technical concepts without overwhelming users. We measure this through Likert scale questions about confidence in understanding the technology and similar open-ended questions and logs (interaction data including time spent on explanatory content and navigation patterns).

For the third research question, we use two survey questions to measure their understanding of technical concepts. We ask "Did the interface clearly explain how your consent allows Silence Laboratories to use your data?" (Yes, Somewhat, No) and "How would you rate the clarity of the information presented about how your data will be used?" (Very Clear, Clear, Neutral, Unclear, Very Unclear). We again analyze differences between interface variants using Chi-Square tests, examining both clarity ratings and explanation effectiveness across

our presentation variants. We track time spent reading first-page explanations. These measurements aim to help us evaluate how well users understand the data usage process.

Each research question examines particular aspects of the consent interface addressing various issues our sponsor, Silence Laboratories, was interested in. In subsection 5.2, we detail our analysis approach, examining both information presentation (first-page) variants and consent option (second-page) variants, along with different grouping combinations within each variant type. The analysis combines quantitative metrics, specifically interaction times and responses to Likert questions with qualitative feedback to build a detailed picture of how different interface elements influence user interaction with privacy consent mechanisms.

4 Implementation

The implementation phase of this research focused on translating theoretical insights and design principles into concrete, testable interface variations. Our approach prioritized functional completeness ensuring that each interface variant accurately represented specific design hypotheses while maintaining consistency in basic functionality. The development process incorporated iterative refinement based on pilot testing, resulting in a set of interfaces that effectively embodied different approaches to privacy consent mechanisms.

This section details the technical implementation of our consent interface variations, including the rationale behind the specific technologies employed. The implementation process was guided by both our research questions and practical considerations for deployment.

4.1 UI Variants

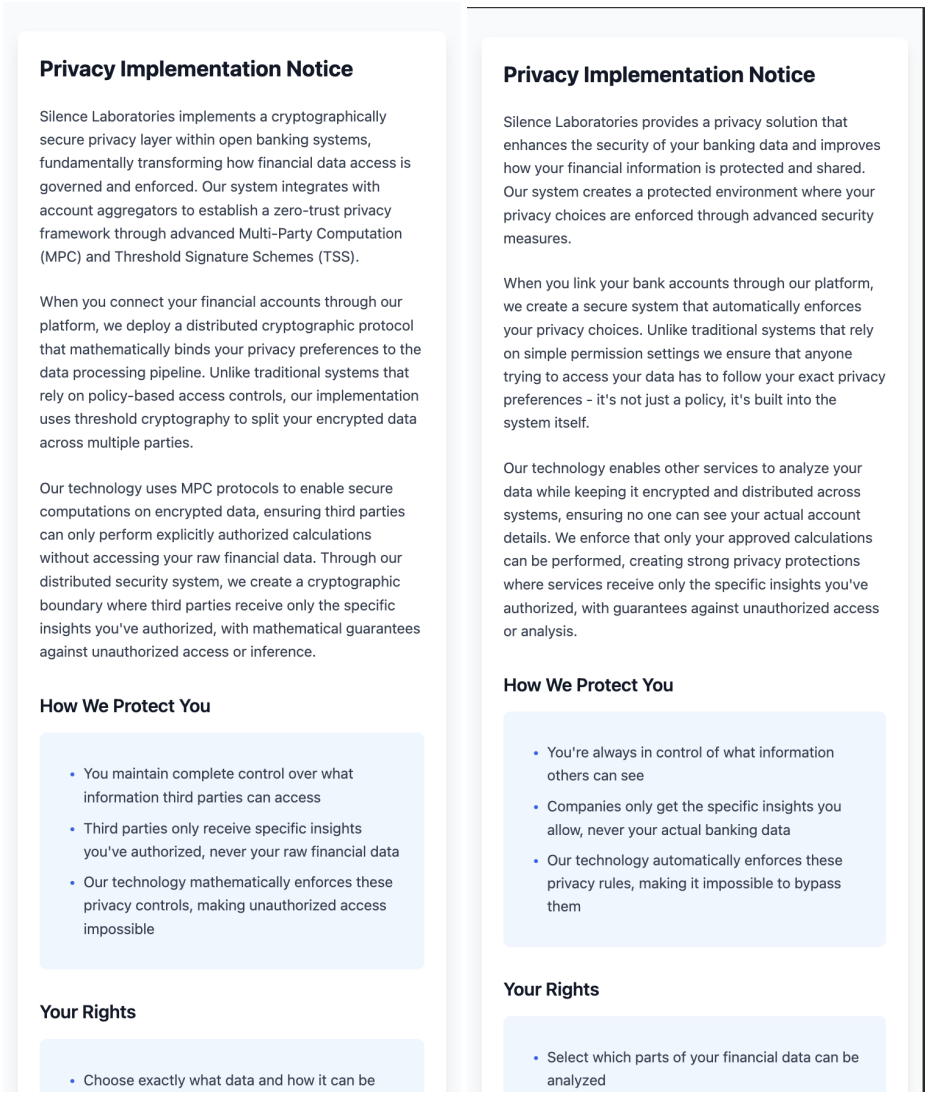
The development of interface variants followed a systematic approach to exploring different dimensions of consent mechanism design. Each variant was crafted to test specific hypotheses about user interaction with privacy controls while maintaining consistency in core functionality. Our implementation encompassed two main segments: **(1) Information Presentation (Privacy Notice)** and **(2) Consent Option Presentation (Privacy Choices)**. For the information presentation variations there existed six distinct interface designs, each representing different approaches to balancing information disclosure and user comprehension. Whereas, we had four variations for consent option presentation aiming to balance user comprehension and user fatigue.

4.1.1 Information Presentation Approaches. The baseline approach establishes two fundamental variants: technical and non-technical presentations. The technical variant, following McDonald et al.'s structured format study, presents comprehensive details with precise terminology to establish an information retention baseline [17]. Figure 2 illustrates this approach.

The non-technical counterpart in the same figure, maintains similar comprehensiveness while employing simplified language, allowing us to evaluate the impact of technical complexity on user comprehension. Building upon these baselines, we incorporated highlighted variations of both technical and non-technical presentations, as shown in Figure 3.

Additionally, we explored layered information presentation and icon-based approaches as presented in Figure 4. The layered approach presents information in progressive levels of detail, while the icon-based variant combines visual aids with explanatory text to enhance comprehension.

4.1.2 Consent Option Presentation. The implementation of consent options explored variations across two key dimensions: text complexity (technical vs. high-level) and interface organization (single-view vs. multi-view). This two-dimensional approach yielded four distinct variants, each

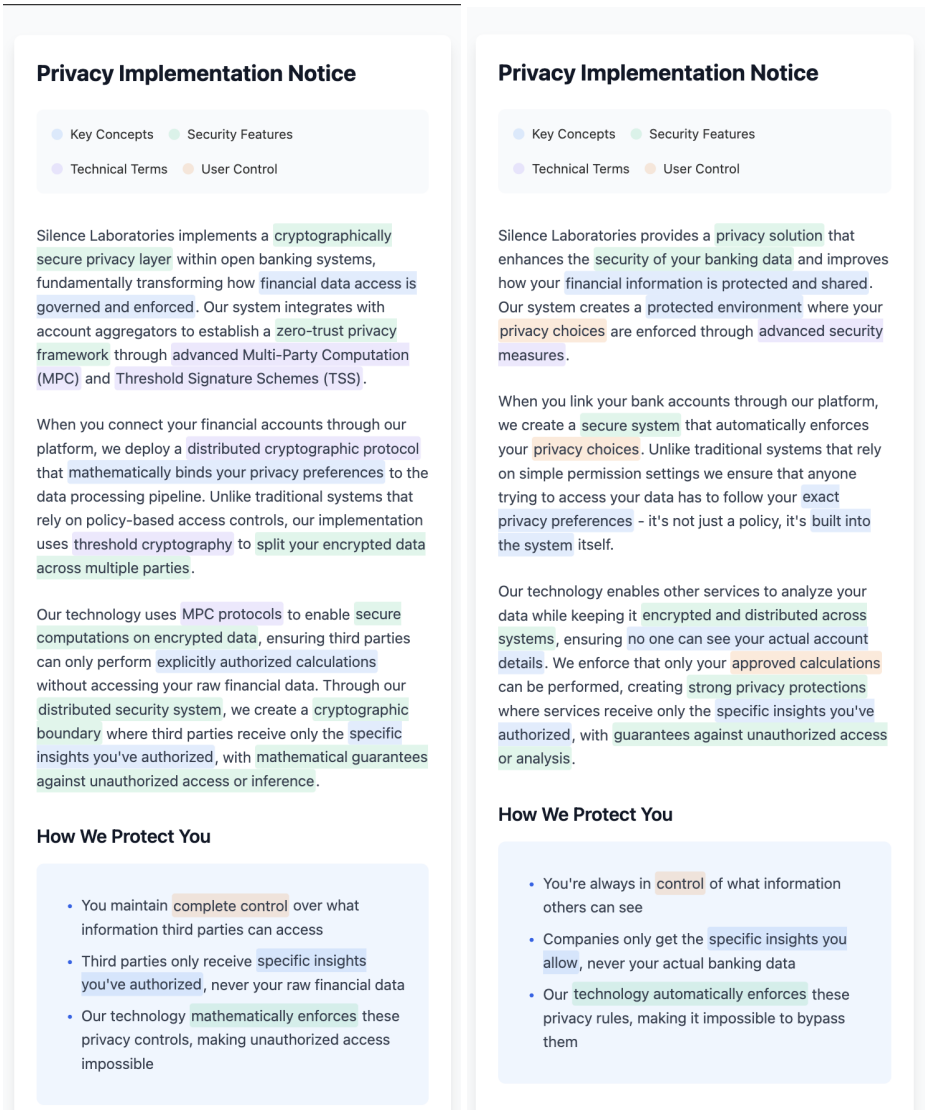


(a) Technical Baseline variant (b) Non-Technical Baseline variant

Fig. 2. Comparison of baseline technical and non-technical variants showing detailed disclosure of privacy-enhancing mechanisms across variants.

representing a unique combination of these attributes to test different hypotheses about user comprehension and interaction patterns.

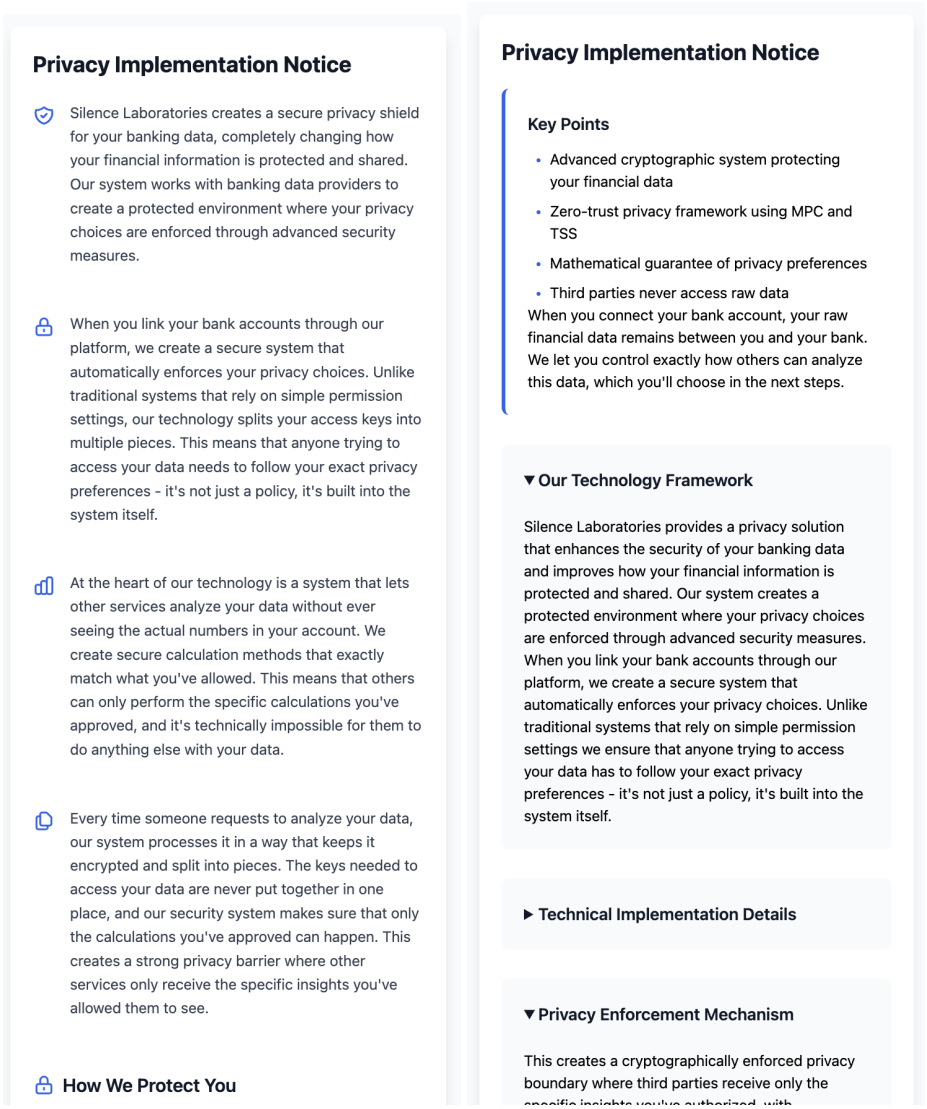
Text Complexity Dimension. The technical variant employed precise terminology and detailed specifications for each consent option, as shown in Figure 5. In contrast, the high-level variant used simplified language while maintaining core information content, focusing on accessibility



(a) Technical Highlighted variant (b) Non-Technical Highlighted variant

Fig. 3. Comparison of highlighted technical and non-technical variants with same text as baseline except highlights.

and general comprehension. Both text variants were implemented consistently across interface organizations to isolate the impact of language complexity on user understanding and decision-making.



(a) Icons + Text variant (b) Layered approach variant

Fig. 4. Comparison of icons augmented and layered approach to privacy information presentation.

Interface Organization Dimension. The single-view organization pattern presents all consent options simultaneously in a comprehensive layout, as illustrated above in Figure 5, where both subfigures 5a and 5b are single-view.

The multi-view variant, on the other hand, segments options into sequential steps, creating a decision path as shown in Figure 6. Each organizational approach was implemented with both technical and high-level text variations, resulting in four distinct combinations:

(a) Options with High-Level Disclosure (b) Options with Technical Disclosure

Fig. 5. Comparison of High-Level and Technical content disclosure for privacy choice interface.

(1) Technical Single-View: Comprehensive technical specifications in a unified interface
(2) Technical Multi-View: Same technical information presented across sequential pages
(3) High-Level Single-View: Simplified explanations in a consolidated view
(4) High-Level Multi-View: Same high-level language distributed across multiple steps

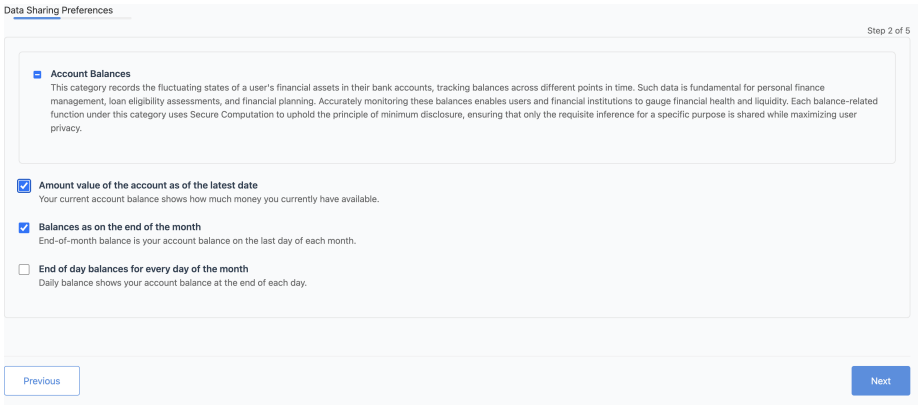


Fig. 6. Sample of multi-page view consent interface where options are sequentially shown to users.

Each variant was accessible across devices and browsers to ensure consistent functionality. The implementation was primarily limited to HTML, JavaScript, and CSS.

4.2 Technical Implementation

The interface variants were implemented using standard web technologies (HTML, CSS, and JavaScript) to ensure broad compatibility. Each variant was made with comprehensive client-side logging capabilities that captured interaction data, including time spent on individual pages, option selection and deselection events, and navigation patterns. The implementation utilized a custom logging system that accumulated interaction data locally in a structured JSON format, recording timestamps, event types, and associated context for each user action. This behavioral data collection was operating alongside but separate from the Qualtrics survey framework, with accumulated interaction logs transmitted to our analysis endpoint upon survey completion.

5 Results & Analysis

The analysis of user interactions with our privacy consent interface variations revealed guiding patterns in how different design elements influence user comprehension and decision-making. Our mixed-methods approach, combining quantitative interaction metrics with qualitative user feedback, provided rich insights into the effectiveness of various interface design choices. The data collection encompassed both explicit user responses through survey questions and implicit behavioral patterns captured through interaction logging, offering a comprehensive view of how users engage with different consent mechanism designs.

This section presents our findings in two main segments: 5.1 pilot study results and 5.2 main study analysis. The pilot study, conducted with a group of 18 participants, provided initial insights that informed refinements to our study methodology. The subsequent main study, involving a larger participant pool (264), generated more comprehensive data that allowed for robust statistical analysis of user behavior patterns and interface effectiveness. Each subsection examines specific aspects of user interaction with privacy consent mechanisms, analyzing both quantitative metrics and qualitative feedback to understand the impact of different design choices on user comprehension and engagement.

Our analysis framework was initially structured around three primary research questions as stated in subsection 1.2:

(1) How can consent mechanisms be designed to balance granularity and user fatigue effectively?
(2) What UI/UX elements are most effective in communicating data usage terms and user control options clearly and succinctly?
(3) How can the concept of consent-bound computation be conveyed to users without overwhelming them with technical details?

However, through our pilot study and initial analysis with our sponsors, two additional critical dimensions emerged:

(4) How can designs ensure that users are making conscious choices rather than passively selecting options?
(5) How to effectively communicate to users that their data remains with the custodian but can be used collaboratively for third-party services?

These emergent questions enriched our analysis framework, leading to a more comprehensive evaluation of consent interface effectiveness through statistical tests including Chi-Square analyses, Spearman correlations, and visualization techniques such as heat maps and grouped bar plots.

5.1 Pilot Study

Our pilot study was conducted in two phases: an initial pre-pilot with live sessions (where researchers directly interact with participants in real-time) followed by a broader pilot deployment. The pre-pilot phase involved 13 participants, primarily consisting of privacy aware participants recruited from within CMU, who participated in observed sessions where they interacted with our interface variations while providing real-time feedback and responding to the survey. These sessions, lasting approximately 10-15 minutes each, allowed us to identify potential usability issues, unclear instructions, and technical constraints in our implementation. Participants' direct feedback highlighted several areas for improvement, including the need to clarify certain questions within the Qualtrics survey which may have two fold responses.

Based on insights from the pre-pilot, we refined our study protocol. Key modifications included restructuring multi-part questions to avoid compound queries, ensuring a link to return to Qualtrics survey at the end of our UI, and implementing more granular interaction tracking. We also adjusted the estimated completion time to better reflect actual user experience. These refinements helped ensure that our study would effectively capture both explicit user feedback and implicit behavioral patterns.

The second phase consisted of a broader pilot deployment with 20 participants recruited through Prolific, serving as a full end-to-end test of our research protocol. This deployment helped validate our technical implementation, particularly the integration between our custom logging system and the Qualtrics survey platform. The pilot confirmed our ability to capture detailed interaction metrics, including time spent on different interface elements and option selection patterns, while maintaining a smooth user experience. Of the 20 participants, 18 successfully completed both the interface interaction and survey components, providing valuable data for preliminary analysis.

This two-phase pilot approach helped strengthen our methodology before the main study. The combination of feedback from the pre-pilot and broader user testing in the pilot deployment helped ensure that our study design would effectively address our research questions while minimizing technical and usability barriers. The pilot phases also validated our participant screening criteria and compensation structure, confirming that the study length and complexity were appropriate for our target participant pool.

5.2 Main Study

Based on the insights gained from the pilot study we launched the survey and collected data from 264 participants.

5.2.1 Study Overview. The main study participants were also recruited through prolific and paid $3.5 for 15 minutes of their survey taking time. We present our complete demographic breakdown,

Demographic Attribute	Value	Count
Age	35 - 44	81
	25 - 34	69
	45 - 54	47
	18 - 24	37
	55 - 64	20
	65 - 74	10
Gender	Female	133
	Male	125
	Non-binary / third gender	6
Highest level ofeducation completed	Bachelor's degree	113
	Master's degree	48
	Some college coursework	44
	High school diplomaor equivalent	35
	Associate degree	16
	Doctorate or professional degree	6
	Prefer not to say	2
How often do youuse digital financialservices (e.g., mobile banking)?	Daily	101
	4-6 times a week	67
	Once a week	50
	2-3 times a week	37
	Never	9
How would you rate yourproficiency with technology?	Very proficient	139
	Moderately proficient	80
	Expert	28
	Slightly proficient	13
	Not proficient	4
Employment Status	Employed full-time	143
	Self-employed	32
	Employed part-time	31
	Unemployed	30
	Retired	10
	Student	9
	Other	9

Table 4. Demographic Attributes and Their Distributions

including age, gender, education, and employment status, in Table **??**. Breaking down individual attributes—we had 81 participants from age group 35-44 representing 30.1% of our participant pool and the largest of the cohort. Similarly as shown in 7 we had 26.1% between 25 - 34, 17.8% between 45 - 54, 14% between 18 -24, 7.5% between 55-64 and 3.2% from 60-74 representing the smallest cohort in our survey.

The survey pool exhibited a gender representation with 50.3% identifying as female, 47.3% as female, and 2.7% as non-binary or third gender. Professional status analysis revealed a predominant

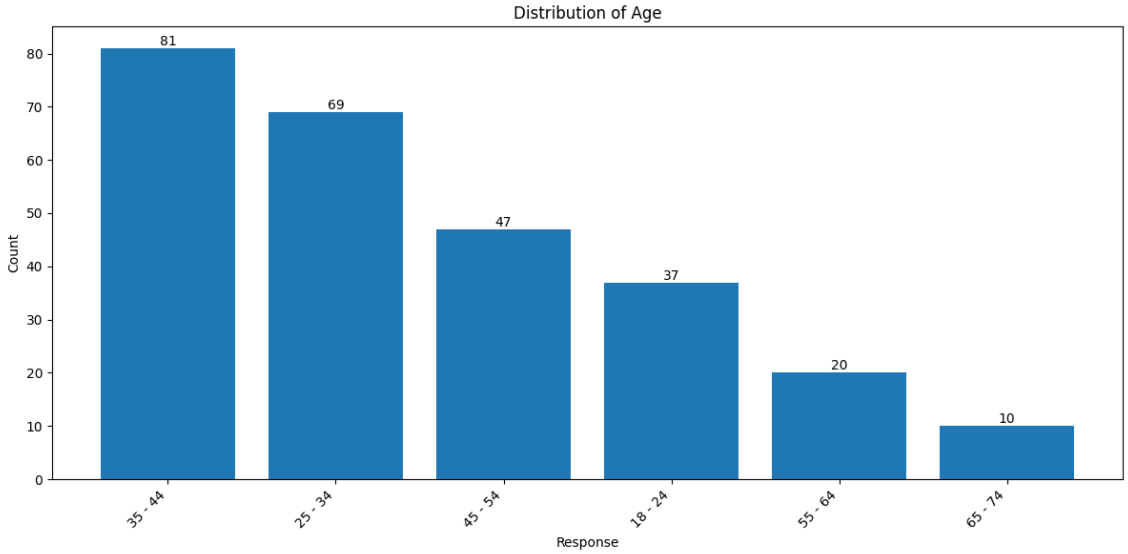


Fig. 7. (Main Study) Age distribution of participants showing representation across key demographic groups

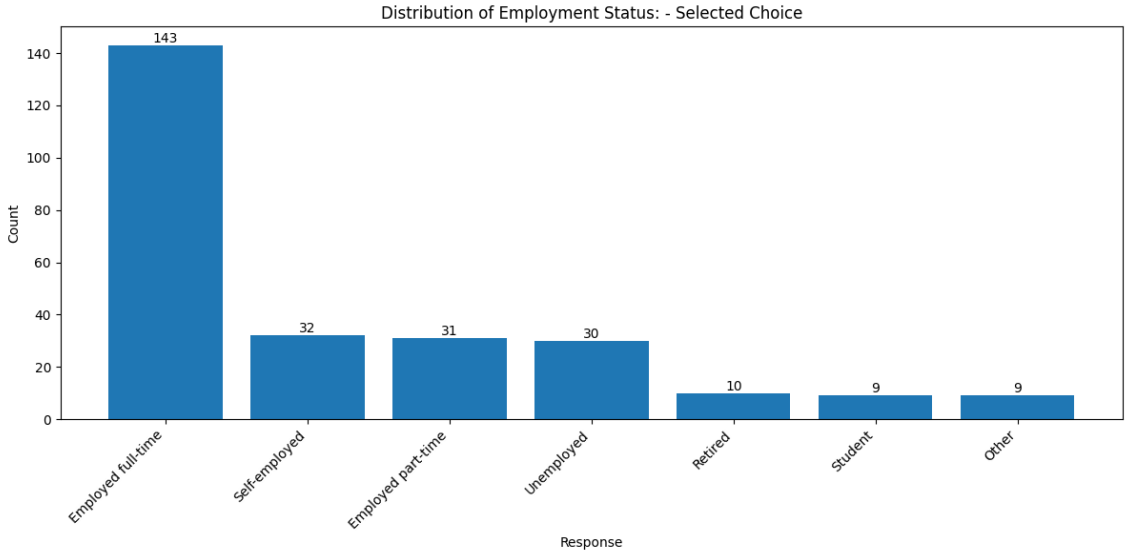


Fig. 8. (Main Study) Employment status of participants

representation of full-time employed individuals (54.4%), participants who were self (12.1%), part-time employed (11.7%), unemployed (11.36%) and retired (3.7%) which is shown in 8. This employment distribution aligns well with our target demographic of active financial service users.

Educational background analysis represented in 9 showed diverse academic achievement levels, with 47.3% having completed Bachelor's degree, 18.18% holding masters's degrees, 16.6% having done some college coursework and the rest High School Diploma(9.4%), Associate Degree (6.0%), Doctorate(2.2%). This educational diversity enabled us to evaluate interface effectiveness across varying levels of academic exposure and technical comprehension which we discuss later in the study.

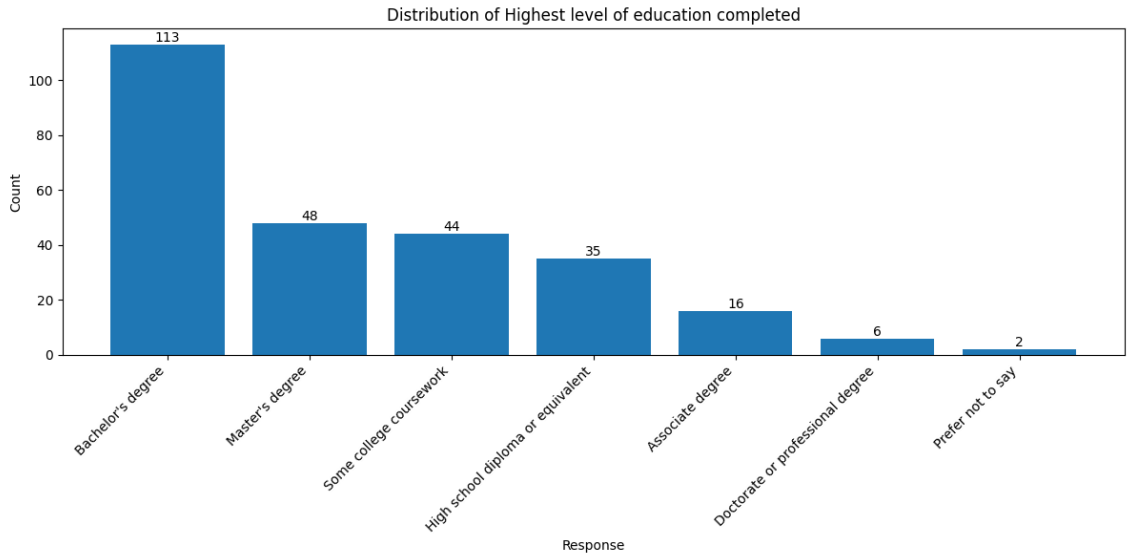


Fig. 9. (Main Study) Education Level of participants showing representation across key demographic groups

Particularly relevant to our study objectives were the participants' technology proficiency and financial service usage patterns. The majority of participants reported being either moderately (38.9%) or very proficient (33.3%) with technology, with additional representation from slightly proficient (16.7%) and expert (11.1%) users. Financial service engagement was notably high, with 33.3% reporting daily usage and an additional 33.3% indicating 2-3 times weekly usage. This high level of financial service interaction provided a strong foundation for evaluating privacy consent mechanisms in financial contexts, as participants brought relevant experience to their interface interactions.

Distribution across variants: For information presentation (Page 1), the randomization algorithm distributed 264 participants across six interface variants examining different approaches to privacy notice presentation. The highlight non-technical variant had the highest number of participants

(n=57, 21.6%), followed by baseline technical (n=49, 18.6%), highlight technical (n=47, 17.8%), baseline non-technical (n=37, 14.0%), icons (n=36, 13.6%), and layered variants (n=38, 14.4%).

The consent option presentation (Page 2) examined four distinct variants exploring combinations of language level and layout structure. The distribution showed balanced allocation: high-level language with single view received 69 participants (26.1%), technical with multiple pages had 68 participants (25.8%), high-level with multiple pages had 65 participants (24.6%), and technical with single view had 62 participants (23.5%). This distribution allowed examination of both single-view and sequential presentation approaches.

Now, we present the results for each of our research questions as described above. The specific survey questions and measurements used to evaluate each research question are detailed in subsection 3.3—Analysis Framework.

5.3 Research Question 1—Balancing Granularity and User Fatigue:

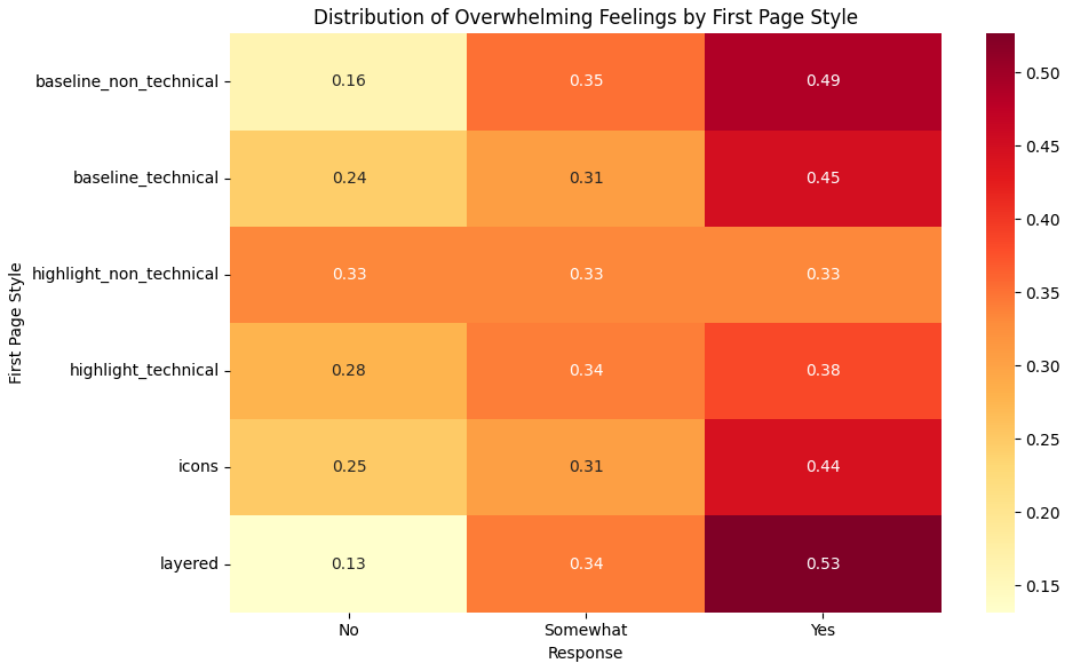


Fig. 10. Distribution of overwhelming feelings by first-page style. Results analyzed in subsection 5.3.

Following our methodology described in subsection 3.3, to examine the balance between granular control and user fatigue, we analyzed two key survey questions: "How easy was it to customize your data sharing preferences within the interface?" (Very Easy to Very Difficult) and "At any point,

did you feel overwhelmed by the amount of information or the number of choices presented?" (Yes, Somewhat, No). Our analysis revealed interesting patterns in how users engaged with different interface variations.

Overwhelming Feelings: We analyzed participant responses on the overwhelming feelings elicited by different first-page styles, as shown in Figure 10. The heat-map, which displays the percentage distribution of overwhelming feelings (Yes, Somewhat, No) across different interface styles with darker colors indicating higher response rates, reveals notable variations across interface styles. Notably, the *highlight non-technical* style was least associated with overwhelming feelings, with 33% of participants reporting "No" overwhelming feelings. In contrast, the *layered* had the highest overwhelming response rates, reporting 59% of participants indicating "Yes." Beyond, these most results seem distributed almost uniformly across variants, achieving a statistically significant result. Upon performing Chi-Square test we get X^2 = 18.52, p = 0.046, indicating a significant difference in overwhelming responses across interface styles, underscoring the influence of design on user perception for our study.

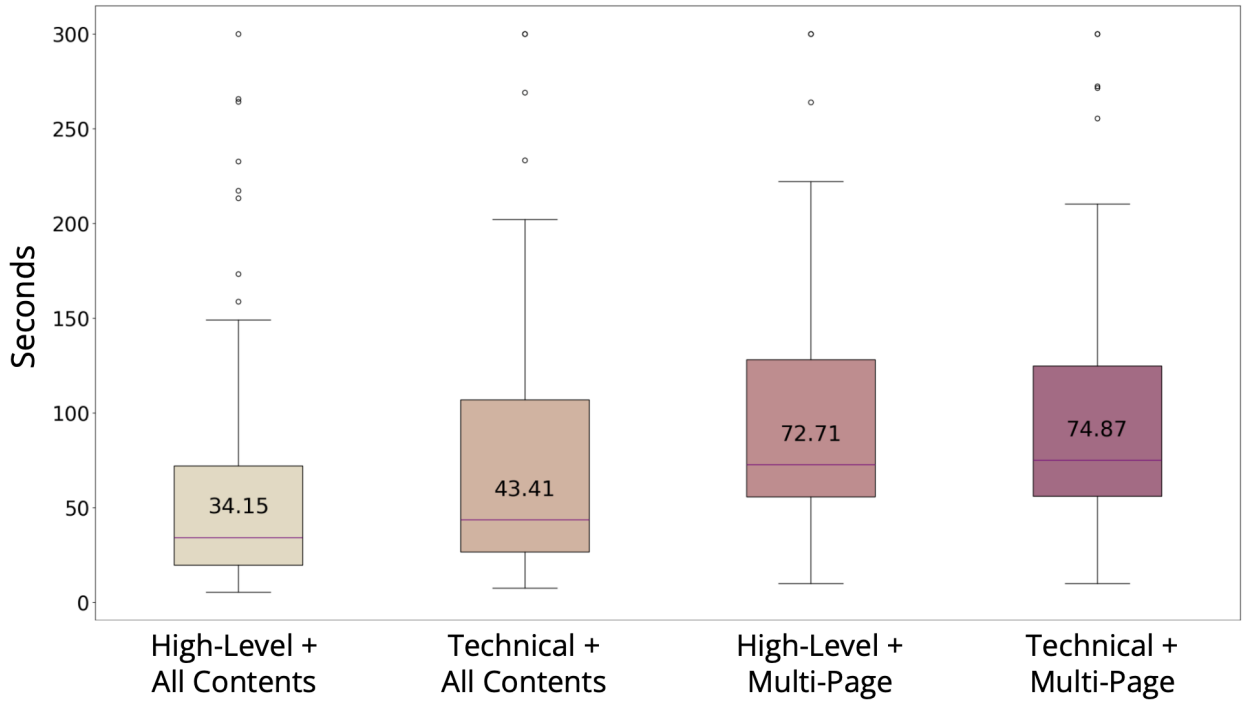


Fig. 11. Time taken per option page distribution between different combinations as analyzed in subsection 5.3.

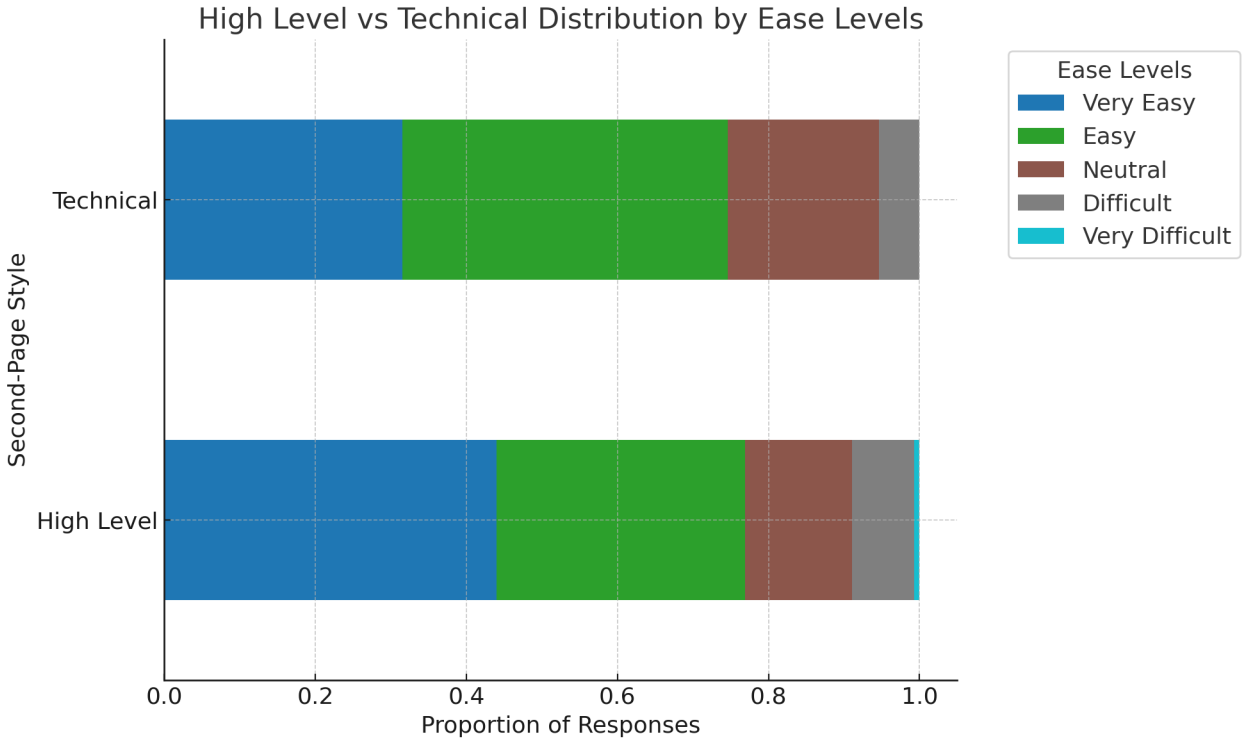


Fig. 12. Distribution of feelings of ease for selecting options for second page interface. Results analyzed in subsection 5.3.

Time of Interaction: As for the second page, i.e. consent options interface—figure 11 presents the time spent by users across different second-page variants. Multi-view variants showed notably higher median interaction times (high-level: 72.71s, technical: 74.87s) compared to single-view variants (high-level: 34.15s, technical: 43.41s). This difference suggests that sequential presentation formats led to longer user engagement with the consent options. We also present the difference in responses for ease of configuration for the second page style in Figure 12. We can observe that for high-level there was a 12.51% increase in this ease for high-level in contrast to technical.

Ease of Customization: Also, given the categorical nature of our survey responses and the independence of observations across interface variants, Chi-Square tests were employed as the primary statistical method to examine relationships between interface designs and user responses. This non-parametric approach was particularly suitable for analyzing our Likert-scale data and frequency distributions, as it does not assume normality and effectively evaluates differences in response patterns across multiple categorical variables. We can see that the ease of customization across variants showed varying patterns, as presented in Table 5. Technical with multiple pages

Table 5. Ease of Customization Ratings Across Interface Variants for Second-Page Styles as detailed in subsection 5.3.

Metric	High-Level Single View	High-Level Multi-View	Technical Single View	Technical Multi-View
		Ease of Customization		
Very Easy	27	32	22	19
Easy	23	21	21	35
Neutral	11	8	14	12
Difficult	7	4	5	2
Very Difficult	1	0	0	0
		Overwhelmingness		
No	15	24	9	16
Somewhat	24	21	22	20
Yes	30	20	31	32

received the highest number of "Easy" ratings (n=35), while high-level with single view had the most "Very Easy" ratings (n=27). Chi-Square analysis for all four option variants of ease ratings (X^2 = 16.26, p = 0.18) and overwhelming feelings (X^2 = 10.63, p = 0.10) showed moderate significance across variants however not statistically conclusive. However, both multi-view variants showed higher proportions of "No" overwhelming responses (high-level: n=24, technical: n=16) compared to their single-view counterparts (high-level: n=15, technical: n=9), despite requiring longer interaction times.

In essence, the multi-view consent interfaces extended user engagement time and demonstrated moderate improvements in data usage recall, though this came at the cost of longer interaction periods compared to single-view formats.

5.4 Research Question 2 — Effective UI/UX Elements for Communicating Data Usage Terms:

To evaluate effective UI elements for communicating data usage, we employed several measurement approaches. Our primary survey questions included "How would you rate the clarity of the information presented about how your data will be used?" (Very Clear to Very Unclear), along with specific retention questions: "Based on the consent interface, what types of data will Silence Laboratories access to provide its services? (Select all that apply)" and "For what specific purposes has Silence Laboratories requested to use your Personally Identifiable Information? (Select all that apply)." We also tracked user interaction patterns through logging UI interactions and compared them with survey responses to compute recall accuracy.

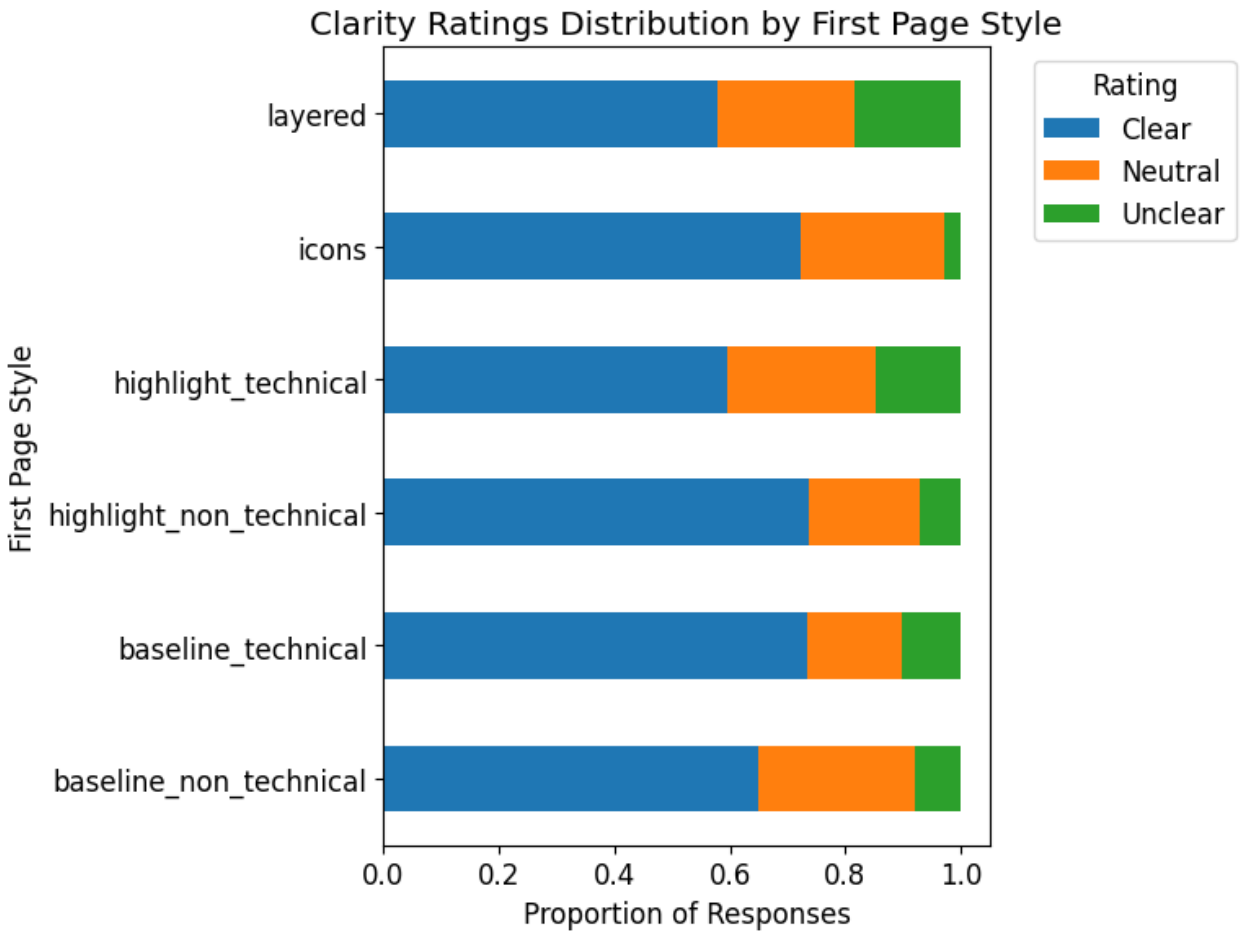


Fig. 13. Clarity ratings distribution by first-page style. Analyzed in subsection 5.4.

Table 6. Clarity Ratings Across Interface Variants for First-Page Styles with raw counts as detailed in subsection 5.4.

Clarity Rating	Baseline Non-Tech.	Baseline Tech.	Highlight Non-Tech.	Highlight Tech.	Icons	Layered
Very Clear	5	15	17	12	6	3
Clear	19	21	25	16	20	19
Neutral	10	8	11	12	9	9
Unclear	3	4	2	5	1	6
Very Unclear	0	1	2	2	0	1

Clarity Ratings: The self-reported clarity ratings for different first-page styles are depicted in Table 6, with Figure 13 combining the counts of "Very Clear" and "Clear" into a single category

("Clear") and "Very Unclear" and "Unclear" into another category ("Unclear") which are then normalized for visualization. The *baseline-technical* and *highlight-technical* styles achieved competing highest proportion of "Clear" responses, indicating their effectiveness in enhancing user comprehension. Conversely, the *layered* style and the *highlight technical* style, showed higher "Unclear" and "Neutral" responses, highlighting its mixed reception among participants. Consistent with our analysis of categorical Likert responses, Chi-Square tests were utilized ($\chi^2 = 9.63$, $p = 0.471$) which revealed no statistically significant differences in clarity ratings across the styles.

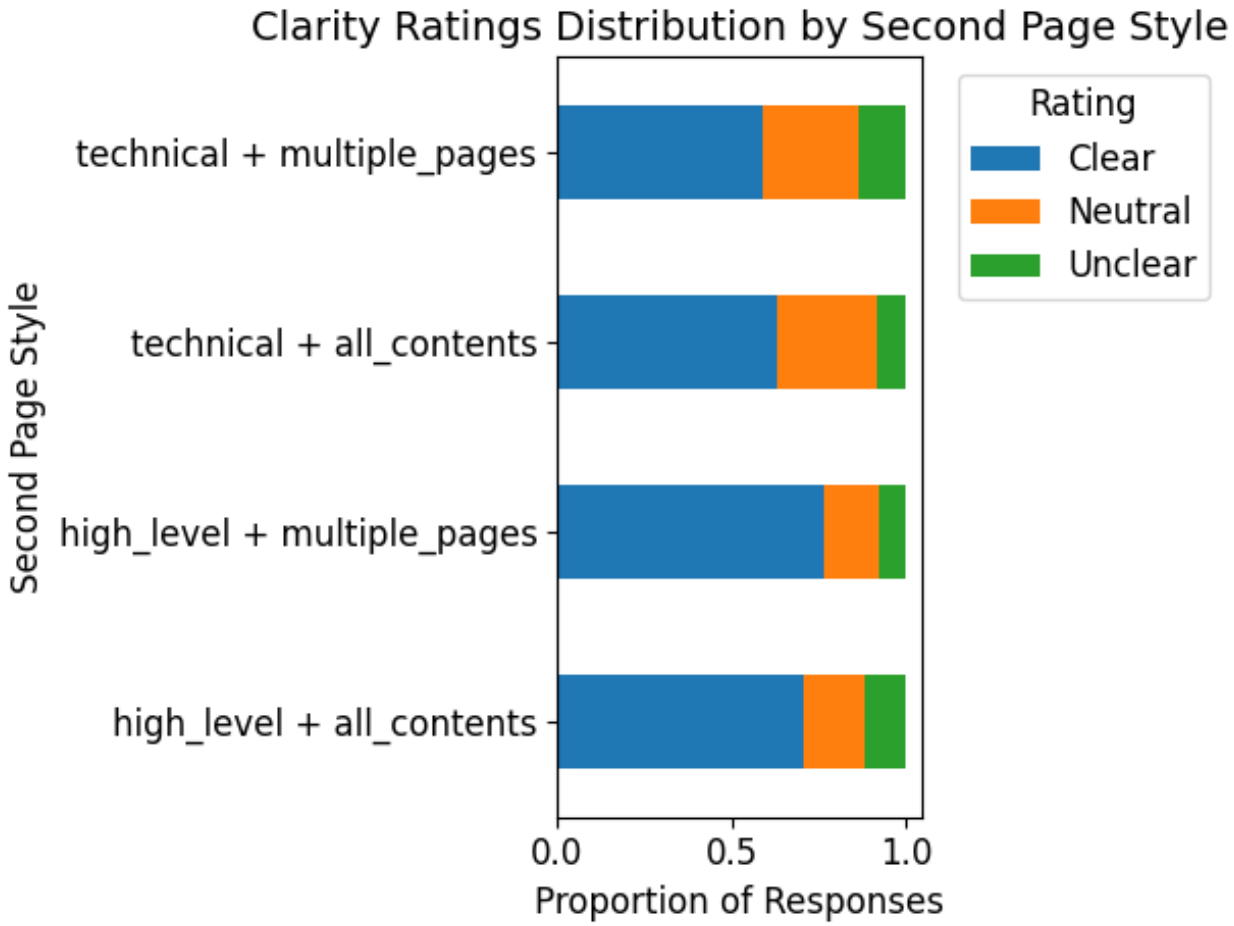


Fig. 14. Clarity ratings distribution by second-page style. Analyzed in subsection 5.4.

Now, for the options interface we present raw counts in Table 7 with combined counts' proportions in figure 14 which highlights the clarity ratings for second-page styles. We see similar mixed reception across the variants this further shown in our statistical analysis using the Chi-Square

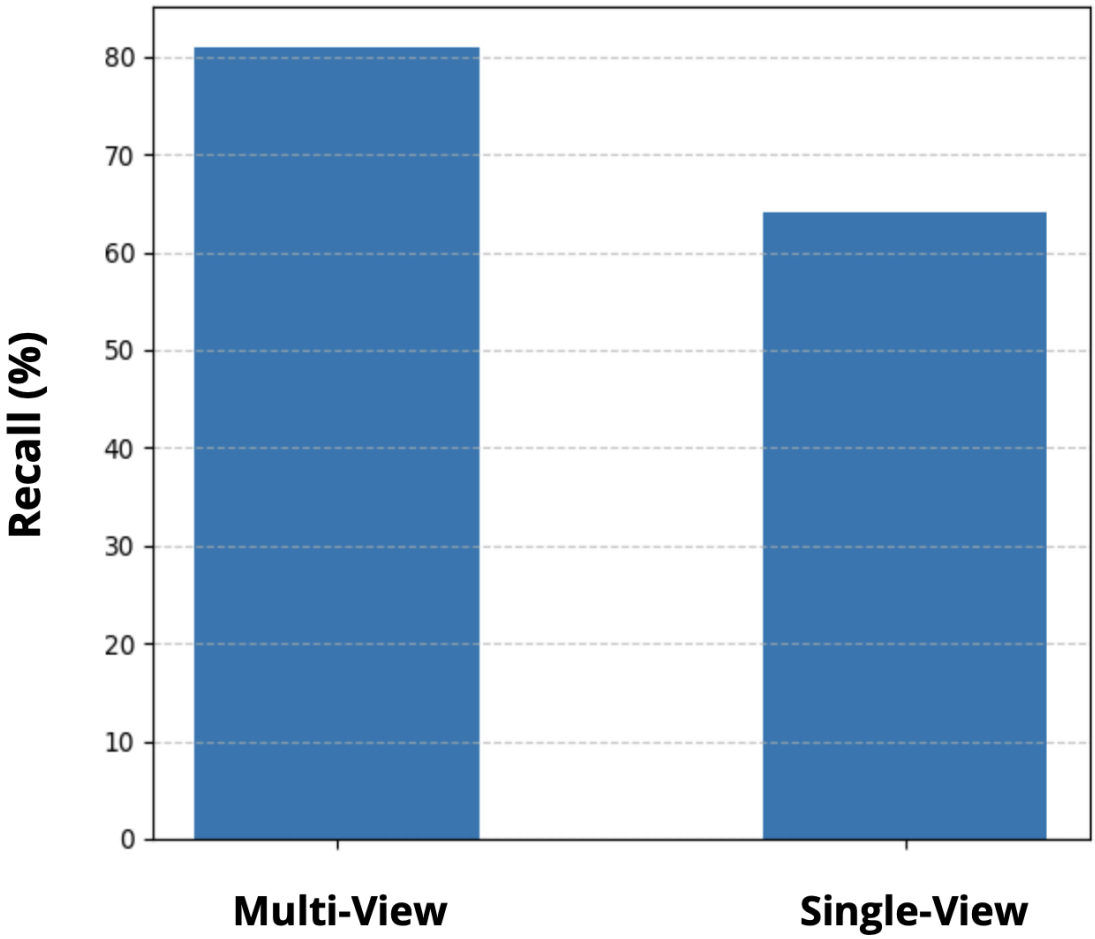


Fig. 15. Recall percentage between multi-view as well as single-view pages. Recall, here, measures the alignment between users' reported and actual data sharing selections as detailed in subsection 5.4.

Table 7. Clarity Ratings Across Interface Variants for Second-Page Styles with raw counts as detailed in subsection 5.4.

Clarity Rating	High-Level Single-View	High-Level Multi-View	Technical Single-View	Technical Multi-View
Very Clear	16	18	15	9
Clear	33	32	24	31
Neutral	12	10	18	19
Unclear	5	4	5	7
Very Unclear	3	1	0	2

test ($\chi^2 = 7.715$, $p = 0.259$) as discussed above, which did not reveal significant differences among the styles. These were across the four option presentation variants.

Data Sharing Recall: However, we did find a significant difference when we measured recall rate of data sharing disclosure from our notice pages. Here, we observe a stark 17% increase when we account for multi-view option interface compared to single-view as shown in Figure 15. Since this is a comparison between two proportions, we employ the Two-Proportion Z-Test, which yields a p-value of 0.0022, indicating a statistically significant result. Also, layered approach achieved 1.2× more clarity than icons.

Ultimately, while highlighted non-technical presentations garnered higher self-reported clarity ratings, quantitative measurements discussed earlier (p=0.259) revealed minimal differences in actual comprehension across presentation styles.

5.5 Research Question 3 — Conveying Consent-Bound Computation Clearly:

Reiterating our methodology from subsection 3.3, to evaluate how effectively consent-bound computation was conveyed to users, we analyzed responses to two key survey questions: "Did the interface clearly explain how your consent allows Silence Laboratories to use your data?" (Yes, Somewhat, No) and "How would you rate the clarity of the information presented about how your data will be used?" (Very Clear, Clear, Neutral, Unclear, Very Unclear). We supplemented these metrics with interaction logs tracking time spent on explanatory content and qualitative coding of open-ended responses.

Table 8. Consent Explanation and Clarity Ratings Across First-Page Styles with raw counts as detailed in subsection 5.5.

Metric	Baseline Non-Tech.	Baseline Tech.	Highlight Non-Tech.	Highlight Tech.	Icons	Layered
Consent Ratings						
No	2	1	2	3	1	0
Somewhat	9	16	19	20	12	11
Yes	26	32	36	24	23	27
Clarity Ratings						
Very Clear	5	15	17	12	6	3
Clear	19	21	25	16	20	19
Neutral	10	8	11	12	9	9
Unclear	3	4	2	5	1	6
Very Unclear	0	1	2	2	0	1

Clarity of Consent Bound Computations: Figure 16 illustrate the self-reported clarity of consent-bound computation explanations provided by Silence Laboratories across various interface styles with raw values for both survey questions presented in Table 8. We observe that there was a significant difference between clarity +9.75% across first page variants between highlighted and baseline variants. Coming back to our standard distribution, we do not see any significant results

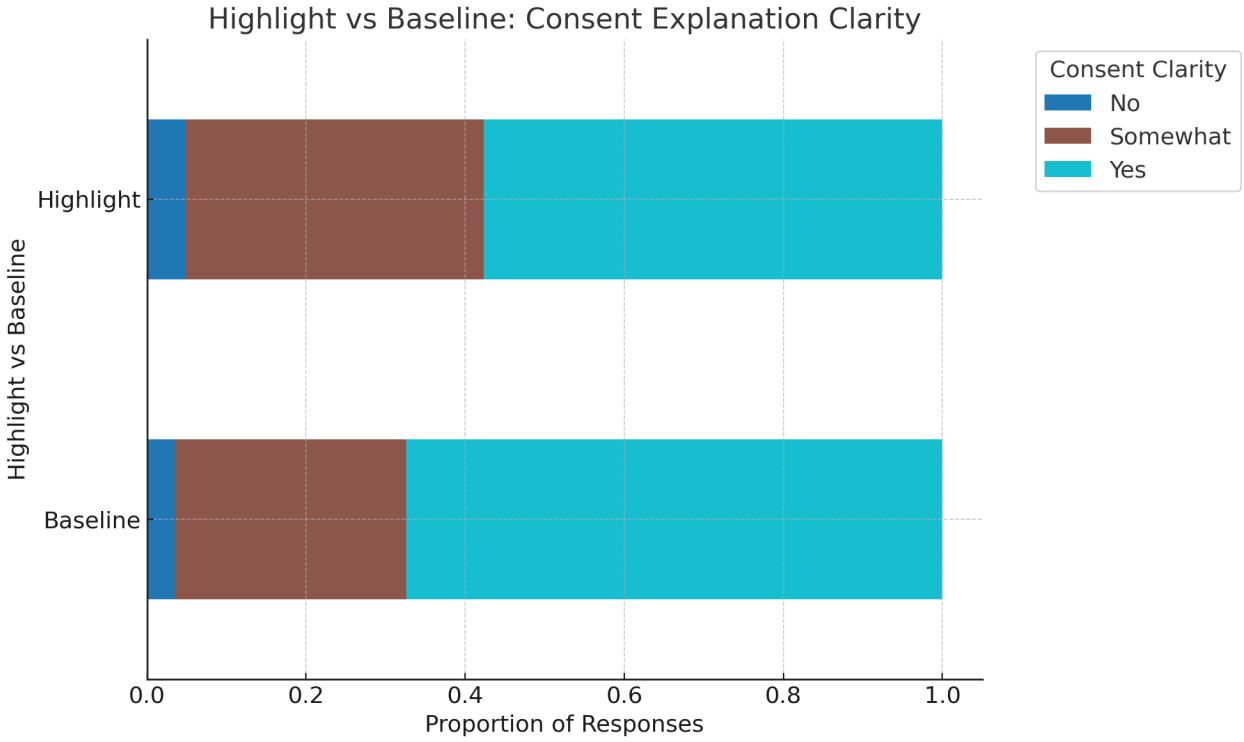


Fig. 16. Consent explanation clarity for the subset of Highlight (grouped across technical and non-technical) and Baseline (grouped across technical and non-technical) for our first-page style variants as analyzed in subsection 5.5.

for across styles for the first page. Observing the difference between baseline and highlight variance we decided to explore group statistics across the four core presentation variants. We specifically conducted statistical tests across the four core variants: Baseline (combining technical and non-technical), Highlighted (combining technical and non-technical), Icons, and Layered. Given the categorical nature of our response data, the Chi-Square test was applied again ($\chi^2 = 24.167$, $p = 0.452$) but did not reveal statistically significant results. As for the explanation we received an even more uniform distribution of responses across styles with Chi-Square test ($\chi^2 = 10.165$, $p = 0.601$) not revealing significant results.

Open-Ended Responses: However, as shown on Figure 17, from qualitative analysis through thematic coding we found that *Highlight + Non-Technical* showed the improved self-reported understanding by 8.48% against the *Baseline + Non-Technical*. Each participant's open-ended response was assigned to exactly one theme during our qualitative coding process. One person from the team coded all responses using the codebook A.3 in a day so as to maintain self-consistency. We

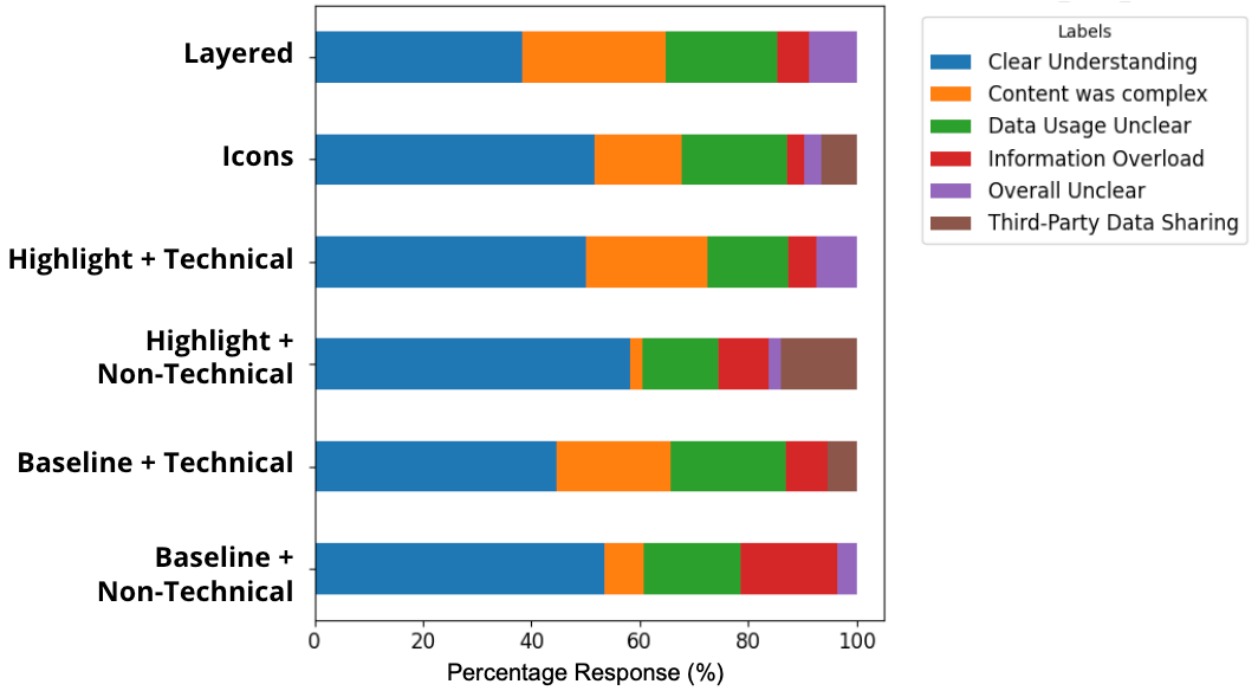


Fig. 17. Plot evaluating self-reported feeling of understanding. Analyzed in subsection 5.5.

also noticed a substantial increase in concern about data sharing by about 13.95%. We believe this is because Highlight with Non-Technical provides higher belief among users that they understand the reasons why they provide consent, which in turn leads to increase in data sharing concerns.

Overall, technical language with highlighting showed marginal improvements in consent-bound computation understanding, though statistical significance remained limited across variants.

Now, for our added research question 4 and 5, we performed statistical analysis over both quantitative and qualitative survey responses. We present those results below.

5.6 Research Question 4 — Ensuring Conscious User Choices:

To examine this question, we analyzed user perception of engagement through specific survey questions. We assessed perceived ease and user experience using questions such as "How easy was it to customize your data sharing preferences within the interface?" (Very Easy, Easy, Neutral, Difficult, Very Difficult) and "Did you find the process of reviewing and providing consent to be?" (Very Quick and Easy, Somewhat Easy, Neutral, Somewhat Time-consuming, Very Time-consuming, Tedious). These questions aimed to measure users' perceived effort in making their choices, including whether they felt they took time to consider their decisions or defaulted to

quick selections. The response patterns helped us assess whether users made deliberate decisions during the consent process.

Perceived Ease of Consent Process: For information presentation variants examining perceived ease of the consent process, the highlight non-technical style received the highest number of "Very Quick and Easy" (n=20) and "Somewhat Easy" (n=18) responses, while baseline technical showed similar positive ratings (n=16 and n=14 respectively). The layered variants combined received notably more "Somewhat Time-consuming" ratings (n=13) compared to other responses. Here, we compare all six variants and conduct Chi-Square analysis to assess perceived UI experience — we learn that significant differences exist across variants (χ^2 = 110.75, p = 0.027). To understand the practical significance of user perception differences, we calculated the effect size using Cramér's V getting a value of 0.26 indicating a moderate effect size.

In consent option presentation variants, high-level with multiple pages received the highest "Very Quick and Easy" ratings (n=26), while technical with multiple pages had the most "Somewhat Easy" responses (n=25). We conducted statistical analysis (Chi-Square) across all four variants, examining perceived ease of customization (χ^2 = 16.26, p = 0.18) and consent process experience (χ^2 = 42.20, p = 0.46) showed no significant differences across variants.

Fundamentally, variations in information presentation showed moderate effects on users' perceived consent process experience (Cramér's V = 0.26), with highlight non-technical style receiving the highest proportion of positive ease ratings compared to other variants.

5.7 Research Question 5 — Communicating Data Custodianship and Collaborative Use:

To examine this question, we used three survey questions to evaluate user perception of data custodianship communication. We analyzed perceived trustworthiness through questions such as "How did the consent interface affect your perception of Silence Laboratories' trustworthiness?" (Greatly Increased Trust to Greatly Decreased Trust), "Did the interface clearly explain how your consent allows Silence Laboratories to use your data?" (Yes, Somewhat, No), and "How would you rate the clarity of the information presented about how your data will be used?" (Very Clear to Very Unclear). These questions measured users' perception of understanding regarding where their data would be stored and how it would be used. The responses helped us evaluate users' perception of whether the interface explained data custodianship and third-party usage clearly. With these metrics established, we analyzed our results across interface variants.

Perceived Consent Clarity and Trustworthiness: For information presentation variants (First-Page Style) as presented in Table 9, the highlight non-technical style received the highest number of 'Yes' responses (n=36) for perceived consent clarity, while baseline technical also performed well (n=32). Both highlighted variants showed strong performance in perceived information clarity,

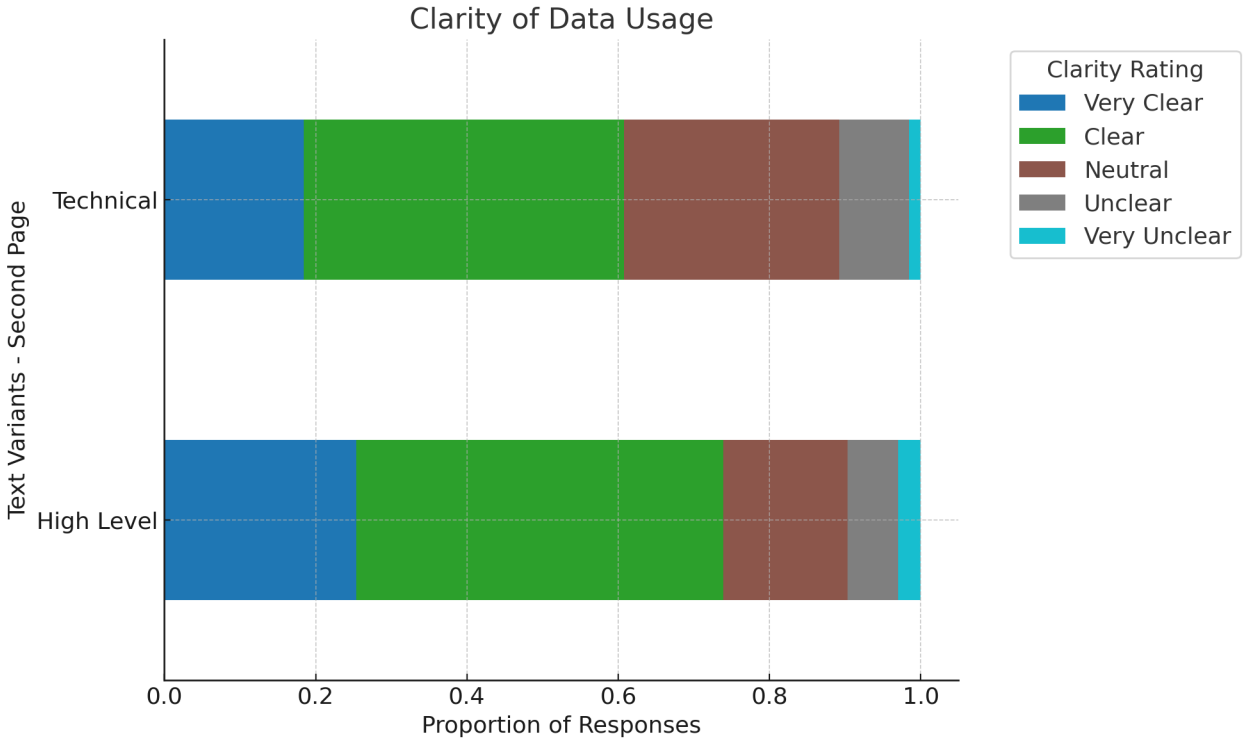


Fig. 18. Plot evaluating High Level vs Technical data usage communication. See subsection 5.7 for result analysis.

with highlight non-technical receiving 42 "Clear" or "Very Clear" ratings combined. The combined layered variants showed lower performance, with 27 "Yes" responses for consent clarity and 22 "Clear" or "Very Clear" ratings for information clarity. Statistical analysis showed no significant differences across variants for perceived trustworthiness (χ^2 = 40.30, p = 0.78) or perceived clarity of information (χ^2 = 24.17, p = 0.45). We also observe grouped responses for second page across technical text and high-level text where in Figure 18. We observe a significantly higher rate of reported clarity 13.11% (very clear and clear) for high-level text in contrast to technical text.

For consent option presentation variants we present our counts in Table 10, both technical implementations achieved high "Yes" responses (n=43 each) for perceived consent clarity, compared to high-level variants (n=41,42 respectively for single-view and multi-view). The technical with single view variant received the highest "Greatly Increased Trust" ratings (n=15), while high-level with single view showed the highest "Somewhat Increased Trust" responses (n=39). Statistical analysis revealed no significant differences across variants for trustworthiness (χ^2 = 27.39, p = 0.29), consent clarity (χ^2 = 3.67, p = 0.72), or information clarity (χ^2 = 12.57, p = 0.40).

Table 9. Survey Ratings Across First-Page Styles for Trustworthiness, Consent Clarity, and Information Clarity as detailed in subsection 5.7.

Survey Question / Rating	Baseline Non-Tech.	Baseline Tech.	Highlight Non-Tech.	Highlight Tech.	Icons	Layered
Trustworthiness Perception						
Greatly Decreased Trust	0	0	2	0	0	1
Somewhat Decreased Trust	4	5	7	8	3	5
No Change	8	8	8	10	10	8
Somewhat Increased Trust	20	24	31	16	16	17
Greatly Increased Trust	4	11	7	11	5	6
Consent Clarity						
No	2	1	2	3	1	0
Somewhat	9	16	19	20	12	11
Yes	26	32	36	24	23	27
Information Clarity						
Very Clear	5	15	17	12	6	3
Clear	19	21	25	16	20	19
Neutral	10	8	11	12	9	9
Unclear	3	4	2	5	1	6
Very Unclear	0	1	2	2	0	1

Table 10. Survey Ratings Across Second-Page Styles for Trustworthiness, Consent Clarity, and Information Clarity as detailed in subsection 5.7.

Survey Question / Rating	High-Level Single-View	High-Level Multi-View	Technical Single-View	Technical Multi-View
Trustworthiness Perception				
Greatly Decreased Trust	3	0	0	0
Somewhat Decreased Trust	7	9	6	10
No Change	9	18	11	14
Somewhat Increased Trust	39	25	28	32
Greatly Increased Trust	9	9	15	11
Consent Clarity				
No	1	2	3	3
Somewhat	27	22	16	22
Yes	41	41	43	43
Information Clarity				
Very Clear	16	18	15	9
Clear	33	32	24	31
Neutral	12	10	18	19
Unclear	5	4	5	7
Very Unclear	3	1	0	2

In summary, high-level language presentations demonstrated a moderate advantage in communicating data custodianship concepts, showing a greater than 13% increase in perceived clarity compared to technical variants.

6 Discussion & Key-Findings

Our analysis of privacy consent interfaces for the open-finance domains selected by us revealed several patterns in how design choices may affect user engagement and comprehension. Through evaluation of information presentation and interaction patterns, we identified design elements that may impact user understanding and trust development. While statistical significance was limited in many comparisons, the combined quantitative and qualitative analysis points to practical implications for designing such privacy consent mechanisms. We discuss some key-findings and takeaways below.

6.1 Key Findings

- Multi-view option presentation changes interaction patterns:
  Introducing a multi-view format for presenting options influenced user behavior. Data usage recall improved by 17%, indicating that breaking information into smaller, sequential chunks enhances the user's ability to retain specific details. Additionally, the average interaction time increased from 34 seconds to 73 seconds, suggesting that users engaged more thoroughly with the content when presented in a step-by-step format.
- Non-technical presentation affects perceived understanding:
  Presenting information in non-technical language positively affected users' self-perceived understanding. Self-reported understanding increased by 8.48%, highlighting the value of simplifying complex concepts to improve user confidence. However, this improvement did not translate to measurable changes in information retention, indicating that while users felt they understood better, their actual retention remained unchanged.
- Highlight language variants also showed improved user experience:
  The use of highlighted language variants further improved the user experience, particularly when paired with non-technical presentations. Reported feelings of being overwhelmed dropped to their lowest levels, with 33% of users stating they did not feel overwhelmed. However, this approach also raised concerns regarding data sharing, leading to a 13.95% increase in reported worries about sharing sensitive information.
- Single-view formats led to noticeably shorter interaction times while achieving comprehension levels similar to multi-view options. This efficiency suggests that while users spent less time engaging with the content, they were still able to grasp the necessary information effectively. However, the brevity of interaction may limit deeper user engagement compared to multi-view formats.

Based on our study of 264 participants, primarily from the US, our findings suggest several considerations for stakeholders in the financial data-sharing ecosystem. For financial application

developers, the data indicates that multi-view consent flows showed better recall rates despite longer completion times among our participants, while non-technical language with highlighting for primary explanations appeared to aid understanding. Financial institutions in similar contexts might consider adopting highlighted non-technical presentations as they showed improved self-reported understanding in our sample, with layered information disclosure appearing particularly helpful for complex financial products. For regulators and policymakers, our limited sample's improved information retention with multi-view consent flows could inform discussions around interface requirements for high-risk financial data-sharing scenarios. The data also suggests potential benefits of standardizing around non-technical language presentations while maintaining access to technical details for transparency.

It's important to note that these findings are preliminary and specific to our study population - further research across different demographics and contexts would be needed to validate these patterns more broadly. Within our sample, combining highlighted non-technical language with context-appropriate page structuring appeared to balance understanding and usability, though stakeholders should carefully consider their specific user base and risk profile when implementing privacy consent interfaces. These recommendations acknowledge that no single interface variation will be optimal for all scenarios.

7 Conclusion

This work examined privacy consent interfaces in account aggregator onboarding through systematic variation of information presentation and consent option structures. The study's approach of separating interface elements into distinct presentation and interaction components allows for evaluation of specific design choices. By collecting quantitative metrics interaction times and information recall alongside qualitative user feedback, we documented patterns in how interface variations affect user engagement.

The analysis framework combining interaction logging, survey responses, and open-ended feedback provides concrete data points for assessing interface effectiveness. Our interface variations drew from established research in privacy notices, visual design, and trust development. This literature-based approach to developing interface variants, spanning from technical versus non-technical language to layered versus visualization-augmented presentations, provides a starting point for validating consent interfaces in other contexts. While this study focused on financial data sharing, similar methods of developing and testing interface variations based on domain-specific literature could transfer to other privacy-sensitive applications.

Through integration of design principles from privacy notice research with empirical user testing, this study evaluates some privacy consent mechanisms. While limited by participant pool size and focus on financial services, the methodology of deriving interface variations from literature and measuring user responses could be adapted for examining consent interfaces across different domains.

8 Limitations

8.1 Study Design Limitations

The study's methodology faced constraints across experimental design and variant implementation. Our interface variants contained methodological constraints in the icon-based design. We implemented a single icon and layered variant rather than technical and non-technical versions of them to maintain a manageable number of total variants for our participant pool size. While this decision helped ensure sufficient participants per variant for statistical analysis, it limited our ability to directly compare the effectiveness of icons/layered variants across different language complexity levels.

The study implemented six information presentation variants and four consent option variants. This scope excluded potential variant combinations that could have revealed additional insights about interface effectiveness. Also, the testing environment presented interfaces in isolation rather than within a complete application context, potentially limiting the understanding of the participants on how these interfaces might function within a completed app.

We did not collect data about specific data types users would share through account aggregators in practice. This missing context reduces the applicability of findings to real-world implementation decisions. The simulated environment also removed external pressures and time constraints present in actual financial decision-making.

8.2 Results Limitations

The participant pool contained 264 participants rather than the planned 400, as many recruits did not complete either the survey or the UI interface interaction components. The geographic focus on U.S.-based participants recruited through Prolific limits generalization to other regions with different privacy regulations and expectations.

Post-study analysis revealed gaps in our measurements. We did not collect data about participants' prior experience with account aggregators. Approximately 3% of participants (8 out of 264) indicated fundamental misunderstanding of the application's purpose in open-ended responses, suggesting more future work.

9 Ethical Considerations

The findings from this study with 264 participants should be considered preliminary rather than definitive. The demographic distribution skewed toward certain age groups and education levels, potentially missing perspectives of other user segments. Given these sampling limitations, implementing these interface designs in production systems requires additional validation with broader,

more representative user populations. Future work should examine how interface variations perform across different cultural contexts, regulatory environments, and user demographics before deployment in privacy-critical applications.

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A Appendix

A.1 Survey

Block 4

Consent Statement

This research aims to conduct a survey on user perception on consent screens. The research team consists of a group of student researchers with background in privacy engineering, information management, and public policy at Carnegie Mellon University.

Procedures

You will be provided with a survey link to visit and complete the questionnaire. The entire survey should take no more than 20 to 30 minutes to complete.

Participant Requirements

We expect you are an adult of 18 years of age and above, in the United States during the time of their participation.

Risks

During this study, you will be asked to view a consent screen and answer questions about whether you were able to understand it and how concerned you were about data disclosure.

There is a risk that this might reveal your personal preferences regarding data sharing.

Compensation and Costs

There would be no cost to the participants.
You will be contributing to a better understanding of consent screens, which will help researchers understand user behavior around consent forms and their effectiveness. This research will enable organizations to better implement and communicate data disclosures and consent mechanisms.

Benefits:

Participants would be provided with $3.5 .

Confidentiality

By participating in the study, you understand and agree that Carnegie Mellon may be required to disclose your consent form, data and other personally identifiable information as required by law, regulation, subpoena or court order. Otherwise, your confidentiality will be maintained in the following manner: Your data and consent form will be kept separate. Paper documents will be stored in CMU property and digital documents will be stored under Carnegie Mellon's control. By participating, you understand and agree that the data and information gathered during this study may be used by Carnegie Mellon and published and/or disclosed by Carnegie Mellon to others outside of Carnegie Mellon. However,

your name, address, contact information and other direct personal identifiers will not be mentioned in any such publication or dissemination of the research data and/or results by Carnegie Mellon. Note that per regulation all research data must be kept for a minimum of 3 years. The researchers will take the following steps to protect participants' identities during this study: (1) Each participant will be assigned a number; (2) The researchers will record any data collected during the study by number, not by name; (3) The data collection process will avoid collecting any personal identifiable information, and our research paper will conduct analysis in anonymous without violating personal privacy.

Rights

Your participation is voluntary. You are free to stop your participation at any point. Refusal to participate or withdrawal of your consent or discontinued participation in the study will not result in any penalty or loss of benefits or rights to which you might otherwise be entitled. The Principal Investigator may at his/her discretion remove you from the study for any number of reasons. In such an event, you will not suffer any penalty or loss of benefits or rights which you might otherwise be entitled.

Right to Ask Questions & Contact Information

If you have any questions about this study, you should feel free to ask them now. If you have questions later, desire additional information, or wish to withdraw your participation please contact the Principal Investigator by phone or e-mail in accordance with the contact information listed on the first page of this consent. If you have questions pertaining to your rights as a research participant, you may reach out to one of our team members Aman priyanshu through apriyans@andrew.cmu.edu. If you want to report concerns to this study, you should reach out to the Principal Investigator, Professor Sarah Scheffler through sscheffl@cmu.edu.

Voluntary Consent

By signing below, you agree that the above information has been explained to you and all your current questions have been answered. You are encouraged to ask questions about any aspect of this research study during the course of the study and in the future. By signing this form, you agree to participate in this research study.

Disclaimer

We use third party applications to manage the progress of the study such as, qualtrics, prolific, google drive. These companies are not owned by CMU. The companies will have access to the research data that you produce and

any identifiable information that you share with them while using their product. Please note that Carnegie Mellon does not control the Terms and Conditions of the companies or how they will use or protect any information that they collect.

Payment Confidentiality: Payment methods, especially those facilitated by third-party vendors (such as Prolific, Visa, Venmo, Amazon, PayPal, and Zelle), may require that the researchers and/or the vendor collect and use personal information (such as your first and last name, email addresses, phone numbers, banking information) provided by you in order for your payment to be processed. As with any payment transaction, there is the risk of a breach of confidentiality from the third-party vendor. All personal information collected by the researcher will be held as strictly confidential and stored in a password-protected digital file, or in a locked file cabinet, until payments are processed and reconciled. This information will be destroyed at the earliest acceptable time. Personal information held by the third-party vendor will be held according to their terms of use policy

By clicking "I agree", it means that you have read the statement and consent.

☐ I agree

Block 4

What is your prolific id?

Block 3

Silencelabs uses advanced data encryption to ensure the security of your data and operates under strict compliance with financial regulations to protect your privacy. Your data will be used exclusively for enhancing your user experience with the app, and you will have the ability to customize and control what data you share.

Before proceeding to use Silencelabs, you are required to review and interact with the following interface, which will present a notice alongside various data-sharing options and ask for your approval.

This scenario is designed to help you understand the kind of data Silencelabs will access and why such data is necessary for the services offered. Your task will be to

interact with the upcoming consent interface as if you were a real user deciding whether to allow Silencelabs access to your financial information.

Click here for consent interface

Default Question Block

Based on the consent interface, what types of data will Silence Laboratories access to provide its services? (Select all that apply.)

- [ ] Personally Identifiable Information
- [ ] Account Balance
- [ ] Budget Logs
- [ ] Transaction Summary
- [ ] Expense Analysis
- [ ] Financial Ratios

For what specific purposes has Silence Laboratories requested to use your Personally Identifiable Information? (Select all that apply.)

- [ ] Providing Personalized financial advice
- [ ] Identification and Regulatory Compliance

- [ ] Marketing and promotional offers
- [ ] Sharing with third-party advertisers
- [ ] Improving app functionality

How easy was it to customize your data sharing preferences within the interface?

- ○ Very Easy
- ○ Easy
- ○ Neutral
- ○ Difficult
- ○ Very Difficult

How would you rate the clarity of the information presented about how your data will be used?

- ○ Very Unclear
- ○ Unclear
- ○ Neutral
- ○ Clear
- ○ Very Clear

Did you find the process of reviewing and providing consent to be:

- [ ] Very Quick and Easy
- [ ] Somewhat Easy
- [ ] neutral
- [ ] Somewhat Time-consuming
- [ ] Very Time-consuming
- [ ] Tedious

How did the consent interface affect your perception of Silence Laboratories' trustworthiness?

- [ ] Greatly Increased Trust
- [ ] Somewhat increased Trust
- [ ] No Change
- [ ] Somewhat Decreased Trust
- [ ] Greatly Decreased Trust

Did the interface clearly explain how your consent allows Silence Laboratories to use your data?

- ○ Yes
- ○ Somewhat
- ○ No

At any point, did you feel overwhelmed by the amount of

information or the number of choices presented?

- ○ Yes
- ○ Somewhat
- ○ No

Suggestions for Improvement: What aspects of the consent interface did you find helpful or would suggest improving?

Please describe any parts of the data use explanation that were particularly clear or unclear to you.

Can you explain what elements of the interface influenced your trust levels?

What specific features of the consent process contributed to your feeling of quickness or tediousness? (List as many as you can figure out)

What could be improved in the explanation to make the consent mechanism clearer?

Age

- Under 18
- 18 - 24
- 25 - 34
- 35 - 44
- 45 - 54
- 55 - 64
- 65 - 74
- 75 - 84
- 85 or older

Gender

- ○ Male
- ○ Female
- ○ Non-binary / third gender
- ○ Prefer not to say

Highest level of education completed

- ○ High school diploma or equivalent
- ○ Some college coursework
- ○ Associate degree
- ○ Bachelor's degree
- ○ Master's degree
- ○ Doctorate or professional degree
- ○ Prefer not to say

Employment Status:

- ○ Employed full-time
- ○ Employed part-time
- ○ Self-employed
- ○ Unemployed
- ○ Student
- ○ Retired
- ○ _____ Other

How often do you use digital financial services (e.g. mobile banking, budgeting apps)?

- ○ Daily
- ○ 4-6 times a week
- ○ 2-3 times a week
- ○ Once a week
- ○ Never

How would you rate your proficiency with technology?

- ○ Not proficient
- ○ Slightly proficient
- ○ Moderately proficient
- ○ Very proficient
- ○ Expert

A.2 scenario

Silencelabs uses advanced data encryption to ensure the security of your data and operates under strict compliance with financial regulations to protect your privacy. Your data will be used exclusively for enhancing your user experience with the app, and you will have the ability to customize and control what data you share.

Before proceeding to use Silencelabs, you are required to review and interact with the following interface, which will present a notice alongside various data-sharing options and ask for your approval.

This scenario is designed to help you understand the kind of data Silencelabs will access and why such data is necessary for the services offered. Your task will be to interact with the upcoming consent interface as if you were a real user deciding whether to allow Silencelabs access to your financial information.

A.3 Codebook

Q1: Improvement Suggestions

Category	**Description/Example**
Navigation/Layout	Interface organization/flow. "The process was easy to navigate."
Understanding Issues	Comprehension difficulties. "I don't know what's happening."
No Feedback	No specific feedback. "none"
Positive	General positive feedback. "Interface is fine."
Security Details	More security info needed. "How is data encrypted?"
Text-Related	Text presentation suggestions. "Improve text size."
Visual-Elements	Visual aid requests. "Provide a visual guide."

Q2: Data Use Explanation

Category	**Description/Example**
Clear Understanding	Comprehension of explanations. "Everything was clear."
Overall Unclear	Lack of understanding. "I don't know what is happening."
No Feedback	No specific feedback. "none"
Content Complex	Difficulty with technical language. "Technical verbiage."
Data Usage Unclear	Confusion about data use. "Unclear how data was used."
Information Overload	Too much to process. "Too much data."
Third-Party Data	Confusion about sharing. "Sharing with third party."

Q3: Trust Level

Category	Description/Example
Detail Level	Trust from detail provided. "Plus for detail."
Negative Trust	Decreased trust from interface. "Less trust with sensitive data requests."
Control Options	Trust from control over choices. "Five steps of privacy."
Design	Trust from interface design. "Clean, modern interface."
Security Focus	Trust from security measures. "Transparent security protocols."
Transparency	Trust from perceived openness. "For personalized services."

Q4: Process Speed

Category	Description/Example
Neutral/Balanced	Neither quick nor tedious. "none honestly"
Text Volume	Comments about amount of text. "There was a lot of text."
Quick Elements	Features making process faster. "Check entire box faster."
Tedious Elements	Features making process slower. "too many steps"
Overall	General comment. "the whole thing"

Q5: Clarity Suggestions

Category	Description/Example
Satisfied	No improvements needed. "Seemed pretty clear."
Better Explanations	Requests for clearer explanations. "Who am I giving info to?"
Simplification	Suggestions to simplify. "Make it shorter."
Language Level	Suggestions about language. "Layman's terms."
Structural Changes	Suggestions about organization. "Consent then options."
Visual Aids	Requests for visuals. "More visual examples."
Don't Know	No specific suggestions. "Don't know"

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