Designing Safer Touch Displays: Digitally Distributing Physical Touch on a Public Display

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Figure 1: The figure presents a common scenario of how smear infection risk is increased through public touch display interaction due to subsequent users touching the screen. We explore adapting user interface layouts between users to help avoid touching the same parts of the screen.

ABSTRACT

Public touch displays, such as ticket machines and self-checkouts, have become ubiquitous but pose increased risks of smear infections due to frequent physical interactions. To address this, we explore dynamically adapting the layout of user interfaces between interactions, spatially distributing touchpoints to reduce infection risk. Guided by expert interviews, we developed a self-checkout prototype with adaptive layouts and evaluated it in a within-subjects, mixed-methods lab study (N=26). Our evaluation compared Vertical and Horizontal GUI Layout Rearrangements against a non-adaptive baseline and assessed the impact of visualizing previous users' touch traces. Although baseline conditions performed better regarding usability and task completion times, qualitative feedback highlighted the perceived benefits of adaptive layouts, especially related to hygiene and privacy. This work contributes to public display design by exploring intelligent interface adaptations and examining the trade-off between ease of use through consistency and enhanced hygienic safety via touch distribution.

CCS CONCEPTS

• **Human-centered computing → Interaction design theory, concepts and paradigms**; **Empirical studies in interaction design**.

KEYWORDS

public display, touch traces, intelligent interface, rearrangement, adaptation

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1 INTRODUCTION

Touch interaction with public displays poses significant health risks due to smear infections [16, 28, 41, 66]. Consider someone ahead in line sneezing into their hands, then touching the screen you intend to use, as shown in Figure 1. Public hygiene awareness intensified since COVID-19, causing more avoidance of shared touch surfaces [21]. Reports from popular media sources have further amplified public concern; for example, fecal contamination was detected on all touchscreen kiosks at six McDonald's locations in the UK, highlighting tangible public health risks [1]. Nevertheless, public touch displays remain ubiquitous due to their intuitive nature, high precision, cost-effectiveness, and durability compared to alternative interaction modalities [29, 48]. This enduring popularity underscores the critical design challenge of reducing infection risks without sacrificing the benefits of touch-based interfaces.

Prior research on hygiene at public touch displays has mainly emphasized hardware-based solutions—for example, self-sanitizing surfaces [54]., or introduced alternative non-touch interaction methods (e.g., mid-air gestures, remote control interfaces) [11, 29, 46]. However, despite the potential hygiene benefits of these alternatives, touch interaction continues to be preferred by users due to its familiarity, precision, and ease of use [29]. Moreover, alternative physical interactions, such as using elbows instead of hands, may unintentionally introduce accessibility barriers, particularly for elderly or mobility-impaired users [11]. In contrast, software-based approaches, such as visually indicating previous users' touch traces, represent promising yet underexplored avenues for enhancing hygiene awareness and modifying user interaction behavior [36]. Consequently, further investigation into adaptive, software-driven methods is necessary to effectively balance usability, accessibility, and hygiene considerations for public touch displays.

In this paper, we use the term ***adaptive displays*** to refer to public touch interfaces that provide opportune, relevant content and personalization by filtering information based on contextual parameters, such as location and time [45]. Similarly, following Wang and Li [67], ***adaptive user interfaces*** automatically adjust their presentation mode and content based on these parameters and user behavior, aiming to enhance efficiency, user satisfaction, and overall experience.

We addressed the existing gap in adaptive public touch display designs aimed at reducing smear infection risks by specifically exploring strategies to rearrange the graphical user interface (GUI) between users. Dynamically rearranging GUI layouts between interactions could inherently conflict with well-established usability heuristics. Specifically, this approach may violate heuristic no. 4 defined by Nielsen [47], namely to *Maintain Interface Consistency and Adhere to Standards*. Hence, our work explores adaptive GUIs and visualization strategies to inform users of prior interactions. By building on previous software-based approaches and visualization concepts [36], we aim to balance trade-offs between hygiene, usability, and consistency. To this end, we pose two research questions:

RQ1 How can we reduce (the perceived) touch overlaps on shared displays through digital interface adaptations?
RQ2 How do the interface adaptations impact the perceived usability?

We began our investigation by conceptualizing three distinct adaptive strategies through collaborative brainstorming among the authors: the Raindrop strategy, the Rule-based strategy, and the Priority-based strategy (see Figure 2). These strategies were subsequently evaluated through expert interviews (N=4), which identified the Rule-based strategy as the most promising due to its balance between effectiveness, usability, and practicality. We implemented this strategy within a simplified grocery ordering prototype to facilitate empirical evaluation. A within-subjects, mixed-methods laboratory study (N=26) was then conducted to assess user performance and perceptions across three layout conditions (Baseline, Rearranged Horizontally, Rearranged Vertically), each tested with and without visualization of prior users' touch traces. Our evaluation measured quantitative outcomes (usability ratings and task completion times) and collected qualitative insights through open-ended questionnaires and brief semi-structured interviews following interaction.

Our findings highlight the promise of the Rule-based strategy, particularly when combined with visualized touch traces, for enhancing users' awareness and facilitating hygienic interaction behaviors with public touch displays. Participants reported adapting their interactions in response to both rearranged layouts and visualized touch traces, recognizing potential benefits for hygiene and privacy (e.g., reduced risk of shoulder surfing). However, these advantages were accompanied by notable trade-offs. Task completion times were significantly longer, and perceived usability ratings decreased in conditions employing adaptive layouts or visualized touch traces. Users commonly cited distraction and active avoidance of highlighted touch areas as the primary reasons for diminished usability perceptions. Thus, our results illustrate a tension: while adaptive interfaces and visualization of touch traces effectively encourage hygienic behaviors, they introduce usability compromises that must be carefully considered and managed in public interface design.

Contribution Statement. Our work makes three primary contributions: (1) We introduce three software-based GUI adaptation strategies (Raindrop strategy, Rule-based strategy, Priority-based strategy) specifically designed to spatially distribute user interactions on public touch displays, thus addressing hygienic concerns. (2) We present empirical findings from a controlled, within-subjects laboratory study (N=26), detailing the effectiveness, limitations, and user perceptions of the Rule-based strategy in combination with visualized touch traces, highlighting the practical trade-offs between hygiene and usability. (3) We articulate the broader implications and design opportunities of adaptive GUI strategies, emphasizing their potential to enhance privacy and safety in public interactions, and providing methodological insights for balancing usability heuristics with adaptive interface designs.

2 RELATED WORK

To contextualize our research, we introduce existing research related to pathogens in public touch display interaction, hygienic public displays, and usability heuristics for graphical user interfaces (GUI).

2.1 Pathogens on Public Touch Displays

The COVID-19 pandemic has spurred research on touchless interaction alternatives in Human-Computer Interaction [14, 22, 31, 43, 55, 68]. However, even post-pandemic, the ubiquity of public touch displays poses a credible risk for fomite-mediated disease transmission, remaining a continuous challenge [13]. Similarly, Gerba et al. [23] conducted a study on public touch displays as reservoirs of opportunistic pathogens, revealing that grocery store touch screens commonly carry enteric bacteria and higher levels of general bacteria. We suspect a similar situation for other public touch displays. Di Battista [13] quantified this risk, estimating that about 3 in 100 users could contract an infection from public touch displays. This underscores the potential of public touch displays as infection transmission centers, highlighting opportunities for research into hygienic interactions. Using computer simulations and Quantitative Microbial Risk Assessment, Di Battista [13] also examined whether public touch displays could transmit enough pathogens to cause infection. Contrary to the expectation that more touches increase infection risk, they discovered that while pathogens accumulate, a corresponding amount is removed from the system. Furthermore, the high concentration of pathogens on seldom-cleaned public touch displays is exacerbated by fixed user interface elements like *OK* or *Pay Now* buttons, leading to repeated touching of small areas. Altogether, the aforementioned examples emphasize the need to explore pathogen mitigation on public touch displays, particularly considering their ubiquitousness.

2.2 Hygienic Public Display Interaction

Previous research has proposed various tools to address the spread of germs and promote more hygienic interactions, such as gesture-based interaction [31, 68], hand disinfection interventions [32], sanitizing wearables [54], speech interaction [24] or near-field smartphone interaction with public displays [51]. However, most methods differ from our approach to adapting user interface element placement in layouts. One approach is a programmable, sensor-equipped wearable sanitizer by Pataranutaporn et al. [54], which disinfects objects up to 80 cm away. However, its impact on user reception and hygiene effectiveness has not been studied. Huang et al. [29] suggested another approach: a non-hand-based interaction for traditionally hand-based setups. Their work compares two mid-air haptic feedback systems (gesture and haptics) in a web- and Augmented Reality-based virtual airport kiosk for germ spread reduction. Both systems showed comparable accuracy near 100% but mid-air alternatives had higher target selection, while the touch-based system provided a better user experience. This highlights touch interaction as the preferred modality by users in Huang et al. [29]'s findings while optimizing for hygiene.

Alternative approaches to increase hygiene on public displays include elbow interaction or touch trace visualizations. Carter et al. [11] redesigned an interactive installation, shifting from hand-based to elbow-based content access to promote COVID safety. Positive feedback from Swansea residents suggested the prototype's suitability for such conditions. Mäkelä et al. [36] conducted a user study with a public display that visualized previous touch locations via fingerprints and provided hygiene data such as time since last cleaning, last user, and total users. They observed increased demand for hygiene information, effectively communicated through fingerprints, which underscores the relevance of our research on improving hygiene in public touchscreens. Another study by Hirsch et al. [26] explored a handrail that indicates previous users' touches until it undergoes self-cleaning. Their findings show users' willingness to change their touching behavior with appropriate indications and suggest that hygienic solutions enhance user comfort.

Visualizations have been explored further to increase hygienic interaction. Ganal et al. [21] created spatial visualizations of contaminated surfaces in a virtual reality simulation of a student office to demonstrate pathogen spread. They investigated participant behavior with and without visualizations. Similar to [32]'s work, the results indicated that visualization may enhance hygiene awareness, promoting more hygiene-oriented behaviors, which further motivates our work, as we share a similar expectation for the touch trace visualizations we employ. For an animated virtual bonsai reflecting proper or improper hand-cleaning behavior through its animation, Stirapongsasuti et al. [64] found that it significantly increased sanitizer usage.

Therefore, our development of three software-driven Rearrangement strategies was therefore directly informed by findings that users change their touch behavior when shown appropriate hygiene cues [26, 36]. In addition to Stirapongsasuti et al. [64]'s nudging concept, Mäkelä et al. [36]'s suggestion to steer users away from frequently touched screen areas—originally from adaptive smartphone UI research on reachability [36]—strongly influenced our approach to spatially distributing touchpoints for improved hygiene.

2.3 Strategies and Approaches to Adaptive Displays

Adaptive public touch displays are mainly explored for customization and personalization purposes depending on the semantic user input and context [12, 34, 42].

In our work, we want to adapt a public touch display's user interface based on previous users' touch points such that users touch different spots for the same elements to foster hygienic interactions.

Recent research on adaptive user interfaces identified contextual parameters that can tailor information to specific situations and environments, supporting multiple users simultaneously and developing general adaptation models that allow users to configure their own profiles. Parker et al. [53] examine methods for determining user height in a selfie-taking machine study. Their findings indicate that users would benefit from information about the purpose of their first touch. Wang and Li [67] propose an adaptive user interface for extra-large touch displays, positioning menu elements based on user dimensions. Their study shows vertical menus strain shorter users' necks and taller users' trunks, while horizontal menus strain taller users' arms. The adaptive user interface accommodates users from 1.45m to 1.85m, reducing neck, trunk, and arm discomfort. Buschek and Alt [10] proposed *ProbUI*, a mobile touch GUI framework that utilizes probabilistic modeling to generalize target representations into gesture sets, increasing the usability and detection of gesture recognition. In our study, we consider findings from these prior works in our prototype and in defining the Rearrangement strategies.

2.4 Public User Interface Design Considerations

To design and evaluate usable public touch displays, we consider heuristics for user interfaces designed for public [4, 18], and shared multi-user displays [49] to create our snack and beverage vending machine prototype. One relevant guideline is by Franceschi et al. [18], who adapted Nielsen's Ten Usability Heuristics [47] for Large Tabletop Displays, including, e.g., the need to keep *Consistency and Standards* (H4). Both authors stress that consistency aligns words, actions, and situations and reflects in user interface consistency throughout the interaction flow. Furthermore, the usability heuristics from Somervell et al. [62] emphasize, among other aspects, that changing the interface too often hampers users from learning the layout, which goes against our Rearrangement attempt.

Other considerations in public display design concern their attractiveness to engage [30, 58] and understandability, also linked to the information visualization [39, 50]. However, most work concerns mostly large public displays, whereas our focus is on smaller ones, such as check-out displays in supermarkets or fast food restaurants. Nonetheless, we consider learnings by Hosio et al. [27] and Mäkelä et al. [35] about the messiness of real-world impacts on usability as well as visual guidance in the interface design as relevant for our context. To be more specific, the real-world application context matters [27] and can trigger unexpected and unintended real-world impacts on public display interaction [35]. Furthermore, information visualization guidelines and principles recommend screen navigation guidance [50] or emphasizing touch traces to highlight an interface's affordance [56]. These prior works guided our process and prototype development and are the basis for discussing our results below.

3 REARRANGEMENT STRATEGIES AND EXPERT INTERVIEWS

To systematically explore software-driven GUI rearrangement strategies, we conducted an iterative process involving brainstorming sessions, resulting in three strategies: *Rule-based*, *Raindrop*, and *Priority-based Rearrangement*. Each strategy aimed at minimizing touch overlap on public touch displays by dynamically repositioning user interface elements based on prior interactions. These strategies were subsequently evaluated through expert interviews, identifying the *Rule-based Rearrangement* as the most promising solution, given its balance between usability, practicality, and effectiveness.

3.1 Strategies

We developed three GUI rearrangement strategies in two structured, 60-minute brainstorming sessions. All authors collaboratively generated ideas, performed sketches, and engaged with relevant literature to ground and refine the strategies.

Rule-based Rearrangement. This strategy organizes UI elements into groups (e.g., logos, navigation buttons, or menu tabs) to help users recognize elements despite layout changes. Instead of relocating single elements independently, it rearranges entire element groups by swapping or resizing them. Similar adjustments are widely employed in responsive web design (see Figure 2), where headers dynamically become footers or sidebars. . Additionally, internal arrangements within these groups, such as button ordering or alignment, can be adapted to further enhance spatial distribution. The Rule-based strategy leverages the Atomic Design Methodology by Frost [20], systematically combining fundamental user interface components ("Atoms") into larger, more complex structures ("Molecules" and "Organisms"), enabling flexible yet consistent interface adaptations.

Raindrop Rearrangement. The Raindrop strategy dynamically adjusts the user interface layout in direct response to each user's interaction. When a user taps the screen, the system immediately calculates the approximate oval-shaped contact area created by the user's fingertip. It then automatically relocates surrounding user interface elements outward, ensuring their nearest edges remain beyond a predefined *shifting factor*. This buffer helps avoid repeated touches in the same spot, distributing interaction more evenly and reducing overlap.

Priority-based Rearrangement. Inspired by Niiro et al. [48]'s grid-based user interface approach, the Priority-based strategy organizes the interface into a structured grid, similar to design systems like Google's Material Design or Bootstrap [40, 63]. Each grid cell and user interface element is assigned a distinct priority level, reflecting their importance and interaction frequency. High-priority cells typically align with key user interaction patterns, such as the commonly utilized F-pattern for reading and interacting with displays [6]. Upon each user interaction, user interface elements are dynamically repositioned using an algorithm similar to insertion sort: touched elements are relocated either to the next available higher-priority cell or swapped with lower-priority elements to maintain spatial distribution. To optimize long-term interactions, once all n cells have been interacted with, the interface resets by rearranging elements according to descending priority, refreshing the spatial distribution for subsequent interactions.

3.2 Expert Interviews

We conducted four expert interviews to discuss strategies for preventing overlap in touch interactions on public touch display user interfaces and to evaluate the strengths and weaknesses of our proposed strategies, focusing on usability and alignment with conventional heuristics.

3.2.1 Participants Recruitment and Approach. Participants were identified through a targeted online search for experts with relevant academic or industrial expertise in Human-computer Interaction (HCI), specifically public display interaction, hygienic interface design, and adaptive user interfaces. Out of 21 contacted via email, four agreed to participate. These experts had extensive HCI experience—ranging from 8.5 to 20 years (mean = 13.1)—and each held a PhD. Interviews lasted approximately 30–40 minutes and were conducted remotely via video call, supported by an online collaborative whiteboard.

After collecting brief demographic data, we introduced a usage scenario (see Figure 1): *A person uses a public touchscreen at a crowded station and observes another user blow their nose and touch the same screen without cleaning their hands*. We then presented two interactive ticket machine screens as stimuli: a start screen with logo, language selection, and common tickets, and a station selection screen with scrollable list and keyboard input.

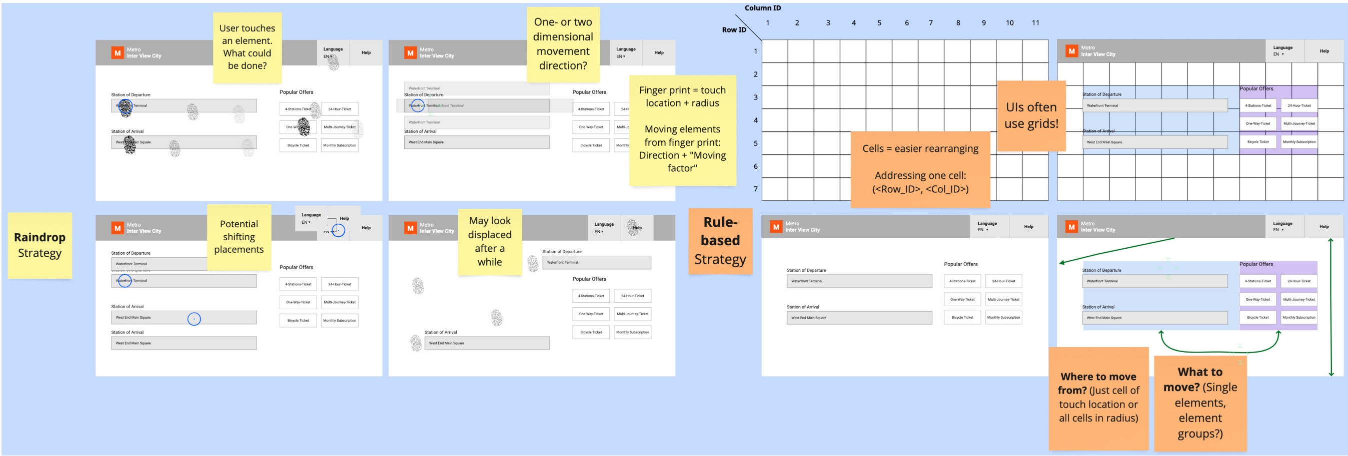

Figure 2: Two Rearrangement strategies from the brainstorming sessions: Raindrop and Rule-based Rearrangement.

We first asked experts to propose their own strategies for reducing touch overlap on the provided UI, focusing on navigational buttons and keyboards, and to reflect on potential usability trade-offs. In a separate step, we introduced our three developed rearrangement strategies—*Raindrop*, *Rule-based*, and *Priority-based*—for detailed feedback. This structure enabled focused discussions on each strategy's usability, limitations, and alignment with established heuristics..[1]

3.2.2 Interview Results. Overall, experts found that the three Rearrangement strategies—the Raindrop strategy, the Rule-based strategy, and the Priority-based strategy—offer different trade-offs in usability and implementation.

The Raindrop strategy allows flexible movement, minimizing touch overlap by spreading elements efficiently. Expert 2 hypothesized it "would perform better, [and] the best" in throughput, but others cautioned it can cause confusing rearrangements, with significant whitespace after multiple shifts. This randomness makes the interface appear "quite random quite quickly," making it "harder for the user to recognize the elements and to find the right element because the logic of the order gets lost" (Expert 2). Expert 3 described it as "ein bisschen unerkenntlich" (somewhat unrecognizable), and Expert 4 found it potentially "confusing," disrupting usability by breaking element relationships.

The Rule-based strategy balances overlap minimization with usability preservation by maintaining the recognizability of the interface layout. Experts noted it offers "a logic that you as a user understand" and makes the interface "still clearer to people [...] and how to use it" (Expert 2), calling it a "clever strategy" that "makes greater sense" by maintaining "consistency of the general layout" (Expert 1). This is achieved by shifting "logische Einheiten" (logical units) or "prinzipielle Bereiche" (principal areas) as groups (Experts 1, 2, 3). While considered a "pragmatic solution" suitable for quick implementation (Expert 3), experts cautioned against "moving the positioning from horizontal to vertical" or "completely changing and arranging by certain rules" (Expert 4), recommending to "shift, not shuffle" and maintain "logische Ablauf" (logical flow) (Experts 2, 3).

The Priority-based strategy emphasizes "keeping the relationships between elements and their hierarchy" (Expert 1). One expert saw it as the "best approach in terms of usability" (Expert 2), while using a tree data structure, presenting a "formales Optimierungsproblem" (formal optimization problem) with academic potential (Expert 3). However, its complexity raises doubts about whether "the trade-off with complexity is really worth it compared to the Rule-based strategy" (Expert 2), as experts noted difficulty understanding "how it works" without examples (Expert 2), and warned that complex rearrangements may "confuse" users who must "search the right place" on public screens (Expert 4).

Overall, experts suggested focusing on the Rule-based strategy as a "pragmatische Lösung" (pragmatic solution), implementable "von heute auf morgen" (overnight) (Expert 3). Although Raindrop "would perform better" in throughput, Rule-based offers a better "trade-off" by maintaining clarity and usability (Expert 2). Experts prioritized "shifting, not shuffling" elements and warned against "completely changing and arranging by certain rules" or altering layout orientation, as this would "break interface design guidelines" and "might confuse" users (Experts 2, 4). They emphasized maintaining "consistency" and the "general look and feel of the screen" in multi-user and single-session scenarios (Experts 1, 3). To ensure usability and accessibility, they recommended adhering to design principles, including "Nielsen's heuristics" [47], and ensuring variants are "gleich zugänglich" (equally accessible), particularly regarding element size (Expert 3). Overlap considerations should include wholly and partially overlapping touches.

3.3 Setup and Prototype Design Decisions

Following the experts' recommendations, we implemented Rule-based Rearrangement in a snack and drink machine prototype (Figure 3). We used an Acer T232HL (23-inch, 16:9) touch display as a device as its size and interaction resemble common public interfaces. The Baseline layout, inspired by McDonald's kiosks, includes key workflow screens: Welcome, Product Category, Product Item,

[1] We provide the collaborative whiteboard setup walked through during the interviews in the supplementary files.

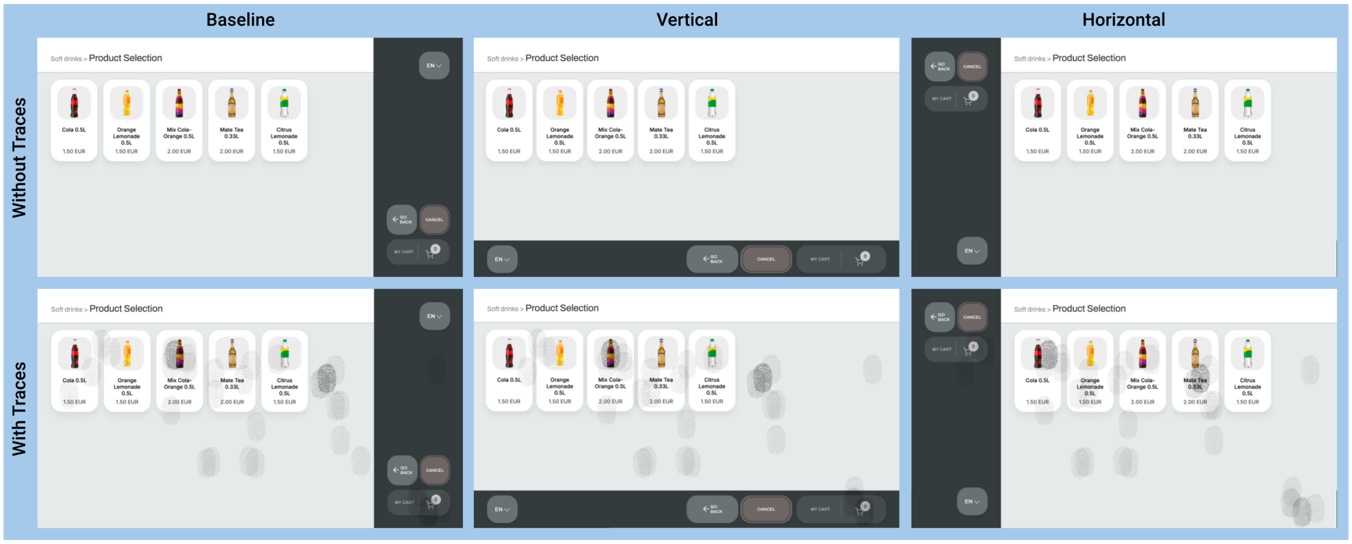

Figure 3: All conditions experienced by each participant, With Traces and Without Traces as well as Baseline, Horizontal and Vertical layouts.

Product Amount (adding to cart), Order Review, Payment, and Confirmation. The user interface further follows usability heuristics emphasizing minimalist design, limited color usage, high contrast, clear buttons, and meaningful icons [2, 44, 47, 52]. We enhanced accessibility by differentiating user interface elements by shape and size instead of color and tested the prototype for color blindness using *SimDaltonism* [17].

To simulate Rule-based Rearrangement, we created two alternative layouts by shifting primary touch areas horizontally (RH) and vertically (RV) relative to the baseline, see Figure 4. The prototype is adaptable, with predefined layouts and Rearrangement occurring before runtime for study comparability.

We followed Mäkelä et al. [36] and visualized touch traces using artificial black-colored fingerprint images at 10% opacity, allowing overlaps to darken while keeping content visible. To prevent excessive overlap for users with larger fingers, we chose the maximum recorded dimensions (25.8 mm width, 17.1 mm height) from McMurchie et al. [38]'s dataset. Selecting an average or smaller size could have led to more unintended overlaps for users with larger fingers, which we aimed to avoid while maintaining hygiene.

The prototype was built with HTML, CSS, JavaScript, and ReactJS, following the Model-View-Controller design pattern. ReactJS was chosen for its reuse with static pages and potential for native app bundling, which could be beneficial for follow-up studies. We ran the system of the prototype via Node.js on a local machine to ensure seamless interaction during the study. Design iterations were based on authoring team feedback, and the prototype was tested in a pilot study (n=2) with university lab staff, using the same procedure as the primary study (see 4). Formal testing was not a primary concern, as we designed the prototype for a controlled lab study with regulated user input.

4 USER STUDY

Building on the expert-validated rule-based rearrangement strategy, we tested two layout variants ('Rearranged Vertically' and 'Rearranged Horizontally') alongside a baseline. Each layout was combined with two trace design conditions — indicating whether prior touches on the screen were visually shown ('With Traces') or hidden ('Without Traces') — in a within-subjects study, resulting in six experimental conditions experienced by each participant.

The study received ethics approval from the first author's Ethics Institution Board.

4.1 Participants & Recruitment

We recruited participants through an announcement on the National Research Network and distributed it via university-related mailing lists and channels. Eligible participants had to be at least 18 years old, proficient in English, and familiar with public displays like fast-food kiosks or ticketing machines. The study included 26 participants, 14 self-identified as men, 10 as women, 1 as non-binary/genderqueer, and 1 as diverse. The participants' ages ranged from 19 to 32 years, with a median age of 25 years. Regarding education, 15 participants had a higher education entrance qualification, 9 held a bachelor's degree, and 2 a master's degree. Most participants (21) were university students, while 2 were trainees and 2 worked full-time. One participant provided a free-text job title, which remained unclear. Four participants were left-handed, which approximately aligns with the 10–15% prevalence in the general population [37]. Participants frequently interacted with public displays: 2 used them daily, 14 at least once a week, 9 at least once a month, and 1 less than once a month. All participants had prior experience with touch-based public display interaction.

4.2 Variables

The study included two independent variables:

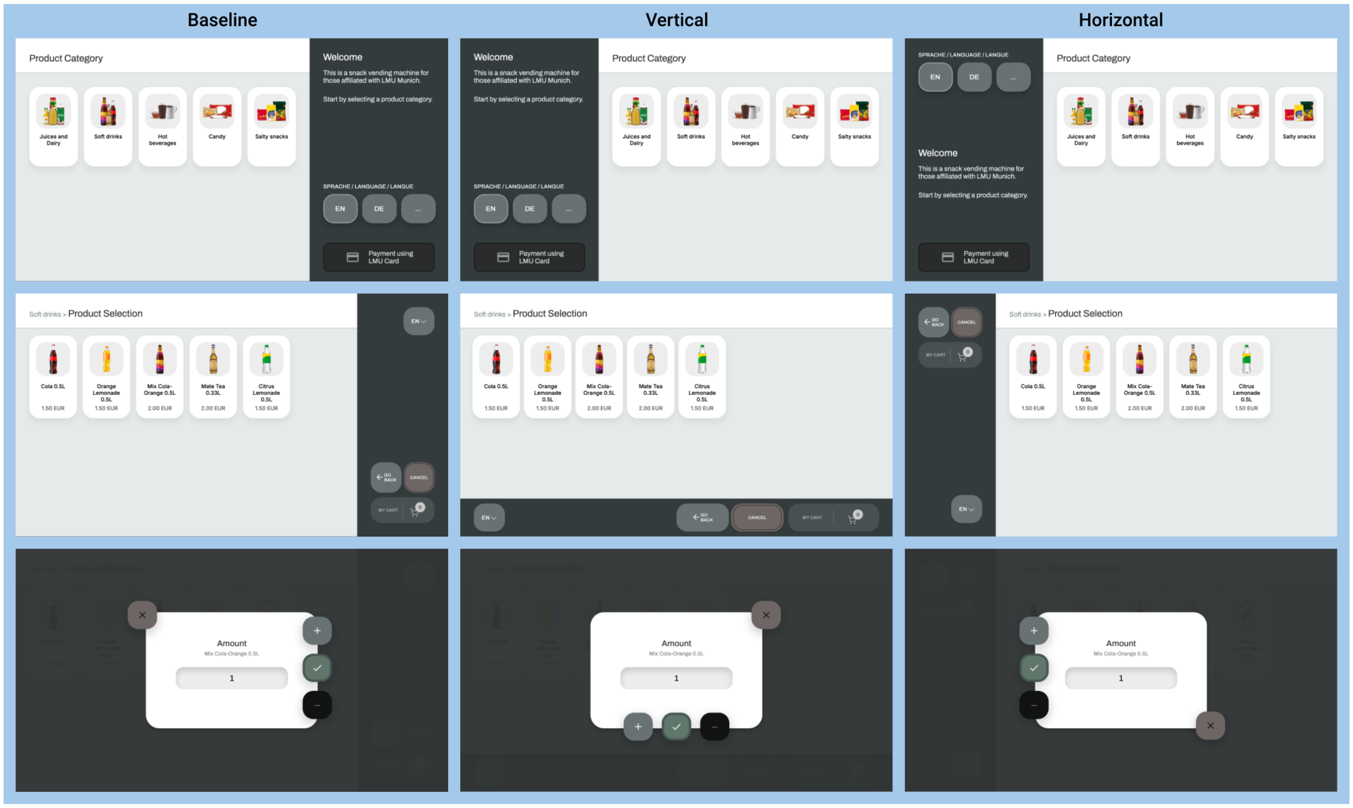

Figure 4: Comparison of select screens showcasing Rule-based Rearrangement as applied in the prototype

(1) *Layout* with three levels: Baseline (B), Rearranged Horizontally (RH), and Rearranged Vertically (RV).
(2) *Traces* with two levels: 'With Traces' (TR) and 'Without Traces' (noTR).

We measured two dependent variables:

(1) *Task Completion Time*, the time participants took to complete each task. We recorded each touchpoint with a timestamp and stored the data in a JSON file, organized by participant, task, and factor combination, starting from the first tap on the start screen to the final 'Pay' tap. Participants were informed that an interaction round starts by tapping the first screen and that the last tap in a session was tapping on 'Pay' on the checkout screen.
(2) *Perceived Usability Score*, reflecting participants' evaluations of the user interface on a 7-point Likert scale for usefulness, ease of use, enjoyment, and behavioral intention using online questionnaires.

4.3 Questionnaires & Interview Questions

We collected qualitative and quantitative data about demographics and user experience in pre-study, interim, and after-study questionnaires. On a separate laptop, questionnaires were provided via soSci, a university-licensed survey tool. We provide all questionnaires in the attachment for further details (see section 9).

Pre-Study Questionnaire: Collected demographic data, including age, gender identity, education level, occupation, handedness, and frequency of public display usage. It also assessed hygiene awareness and safety perception (e.g., "*When interacting with public displays, I think about the possible hygiene risks associated with shared surfaces*").

Interim Questionnaire: Included the hedonic TAM [65] measurements for usability with a 7-point Likert scale, which extends the Technology Acceptance Model (TAM) for hedonic information systems.

Post-Study Questionnaire: Examined participants' preferences regarding adaptive public display layouts and touch traces, as well as their perceived effects on hygiene, privacy, and usability (e.g., "*I think rearranging layouts increases the display's hygiene.*"). It included open-ended questions on trust, benefits, and drawbacks of adaptive interface conditions.

Interview Questions: Investigated participants' preferred user interface and their reasoning, including any experienced issues. Additionally, participants were asked whether they trusted adaptive displays more, as well as their perceived benefits and drawbacks of adjusting interfaces (e.g., "*What benefits, if any, do you personally see in these kinds of adjusting interfaces for public displays?*").

4.4 Tasks

Participants experienced 4 pre-defined tasks to complete in each condition:

Task 1 Set the language to English. Select the category *Soft drinks* and choose one *Citrus Lemonade*. Complete the purchase.
Task 2 Select the category *Soft drinks* and choose two *Citrus Lemonades* and one *Cola*. Complete the purchase.
Task 3 Set the language to English. Select the category *Soft drinks* and choose two *Colas*, one *Mate Tea*, and one *Orange Lemonade*. Complete the purchase.
Task 4 Select the category *Soft drinks* and choose two *Citrus Lemonades* and one *Cola*. Go to the shopping cart and change the order to one *Citrus Lemonade* and two *Colas*. Complete the purchase.

4.5 Procedure

The study was conducted in a controlled laboratory setting at the first author's research institute and comprised three phases: pre-study, main phase, and post-study. During the pre-study phase, participants were briefed on the study goals, procedures, data privacy, and their rights, after which all provided informed consent. Participants then completed a pre-study questionnaire capturing demographic information, hygiene awareness, and perceptions of safety related to public display interactions. Following this, each participant performed a practice interaction round using the Baseline layout to become familiarized with the snack and beverage ordering prototype.

In the main phase, participants engaged with the snack and drink ordering interface presented on a large, touch-enabled display. Each participant completed all six experimental conditions (the three layouts combined with two trace designs), performing the four predefined shopping tasks in each, resulting in 24 interaction rounds per participant. The order of conditions was fully randomized, while task complexity followed a consistent sequence, progressing from simpler to more complex.

In the post-study phase, participants completed a final questionnaire designed to capture their experiences and preferences. Additionally, each participant engaged in a short semi-structured verbal interview to gather qualitative insights into their perceptions of usability, hygiene, and privacy concerning the interface variations. The entire procedure lasted approximately 30 minutes per participant.

4.6 Data Analysis

We used inferential statistics to calculate the significant differences for the task completion time and the Perceived Usability Score in R following van der Heijden [65]' work, which included the Likert-scale ratings for usefulness, ease of use, enjoyment, and behavioral intention.

Further, we analyzed qualitative data from interview transcripts and open-ended questionnaire responses by applying a deductive thematic analysis according to [7, 8], sorting the data into four themes pre-defined by the authors related to touch traces and layout rearrangements and their effects on *Reaction to Touch Traces*, *Usability Layout Rearrangements*, *Hygiene*, and *Privacy*.

Our data gathering, processing, and storing adhere to EU-GDPR guidelines, including data anonymization by labeling files with alphanumeric IDs. Audio recordings were deleted after evaluation.

5 RESULTS

We evaluated the quantitative data with descriptive and inferential statistics and the qualitative data by transcribing the interview material verbatim applying a deductive thematic analysis [8].

5.1 Quantitative Results

We used inferential statistics to identify potential significant differences between the conditions, testing the data for their normal distribution with the Shapiro-Wilk test first. The Perceived Usability Score data violated the normal distribution conditions (*Shapiro-Wilk*, $p = .007$). Thus, we applied an Aligned Ranks Transformation (ART) ANOVA. A Tukey HSD test with Cohen's d for effect size helped us identify differences between factor combinations. Task completion time followed a normal distribution (*Shapiro-Wilk*, $p < .001$), so we applied a two-way ANOVA and used Tukey HSD *post hoc* tests for significant differences.

5.1.1 Hygiene and Privacy Perception. Table 1 presents the distribution of participants' hygiene awareness and safety perceptions during the interaction. The responses were measured on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). The results show that participants felt rather comfortable with touch interaction despite the potential smear infection risk ($m = 5.0$, $SD = 1.7$) and were moderately aware of the hygiene risks ($m = 4.4$, $SD = 1.9$). Regarding privacy perception, participants were moderately concerned about others observing their input, $m = 4.6$, $SD = 1.8$, while still feeling comfortable with the interaction besides potentially being observed by others ($m = 5.2$, $SD = 1.4$).

5.1.2 Average Task Completion Time. The two-way ANOVA (see Table 2) revealed a significant effect for layout $F(2, 618) = 4.29$, $p = .01$ and traces ($F(1, 618) = 14.12, < 0.001$) on task completion time. Tukey's post hoc revealed that participants completed tasks faster without touch traces and in the Baseline layout condition (see Table 3).

5.1.3 Perceived Usability Score. We could observe significant differences between layouts ($F(2, 150) = 14.01, < .001$) and traces conditions ($F(1, 150) = 12.65, < .001$), see Table 4. The different layout and traces combinations resulted in non-significant differences. Yet, Tukey's post hoc comparison identified significant differences between Baseline Without Traces and Horizontal With Traces ($F(2, 150) = 1.04, < .001$), Vertical With Traces and Baseline Without Traces ($< .001$), and Baseline Without and Horizontal Without Traces conditions ($< .001$). See Table 5 for further details.

5.2 Qualitative Results

Two researchers conducted a deductive thematic analysis following Braun and Clarke [7]'s work of pre-defining themes and analyzing the qualitative data with the six steps as presented in [8] to first define themes, then familiarize with the data and create initial codes, construct and revisit themes based on codes, sort codes to pre-defined themes and iterate on the themes and report the

Table 1: Demographic responses to hygiene risk awareness, comfort despite hygiene risks, concern about observing input, and comfort despite observation.

Response	Hygiene risks awareness	Comfortable with Hygiene risks	Concern about being observed	Comfortable being observed
1 (Strongly Disagree)	4 (15.4%)	2 (7.7%)	–	–
2 (Disagree)	2 (7.7%)	–	5 (19.2%)	2 (7.7%)
3 (Somewhat Disagree)	2 (7.7%)	3 (11.5%)	5 (19.2%)	2 (7.7%)
4 (Neutral)	–	5 (19.2%)	2 (7.7%)	3 (11.5%)
5 (Somewhat Agree)	9 (34.6%)	2 (7.7%)	3 (11.5%)	5 (19.2%)
6 (Agree)	7 (26.9%)	10 (38.5%)	6 (23.0%)	10 (38.5%)
7 (Strongly Agree)	2 (7.7%)	4 (15.4%)	5 (19.2%)	4 (15.4%)
Mean	4.4	5.0	4.6	5.2
SD	1.9	1.7	1.8	1.4

Table 2: ANOVA Task Completion Time: We show the sum of squares (*SS*) and the mean of squares (*M*).

Cases	*SS*	df	*M*	F	p
Layout	693.91	2	346.96	4.29	0.01
Traces	1141.89	1	1141.89	14.19	< .001
Layout*Traces	163.92	2	81.96	1.01	0.36
Residuals	49984.17	618	80.88		

findings. Both researchers pre-defined themes and conducted steps four to six together. One researcher conducted steps two and three of familiarizing with the data and creating initial codes.

Here, we elaborate on the findings related to the four themes **Reaction to Touch Traces**, **Usability Layout Rearrangements**, **Hygiene**, and **Privacy**.

5.2.1 Reaction to Touch Traces. Participants either associated visible touch traces with poor hygiene, which led to a change in behavior, or did not perceive them as real. For example, P1 *"I felt weirdly disgusted despite being aware that the fingerprints are just a graphic element on the screen. I felt a little tense in my body and nervous once I saw the display with the fingerprints, especially when I had to press a button that had no space without a print, so I had to touch a fingerprint"*. However, some participants found the distraction negligible unless it directly obstructed their interaction. Touch traces made it also harder for participants to focus, *"[Touch traces] are distracting, and it is harder to extract the information"* (P24). This may also have been due to the meaning of the traces being unclear initially for some participants, as P19 noted: *"At first I couldn't tell if these were fingerprints from others or my own"*. Similarly, some found the traces too artificial to associate them with real smudges.

Participants also adapted their interaction behavior because of the traces, trying to avoid areas with visible fingerprints; *"I tried to touch on the fields where there were no touch traces."* (P12). Some users reported to have switched to using their knuckles to avoid leaving fingerprints. Touch traces also led to more cautious interactions, e.g., P25 said, *"Seeing previous traces made me slightly cautious, and I tried to touch the display at different points"*. Also, participants learned to use the traces' indication by interacting with different areas on the screen; *"After a while, I appreciated the information, as then I could press the buttons in corners that were less frequently pressed"* (P18). These findings show the potential of visualized touch traces to trigger alternative interaction behavior that may contribute to decreasing infection risk.

Some participants were particularly concerned about fingerprints accumulating on frequently used action buttons. P23 highlighted this issue: *"But still, the fingerprints —especially the ones on the Add and Confirm buttons— can be a real obstacle for my next visit, though I know that buying elsewhere won't promise a cleaner state"*. A common theme was the desire for control over touch traces. Many suggested making traces "optional" or limiting them to certain screens. One participant said, *"If it's optional, it seems to be a good feature"* (P8). A few participants would accept touch traces if they were temporary or optional. Others proposed an alternative visualization, suggesting that rather than highlighting contaminated areas, the system could indicate safer places to touch: "*It would be nice to see where not to touch the display.*" (P16).

5.2.2 Usability Layout Rearrangements. Participants found the Baseline layout easy and intuitive, whereas rearranged layouts could be challenging, *"It's a higher effort to learn it again every time"* (P15) or *"I need to relearn that, it slows me down"* (P1). In addition, touch traces increased interaction time, with one user saying, *"It took longer because I was avoiding touched spots"*.

Other participants adapted easier to new interface positions, learning to increase the interaction speed. For example, when encountering layouts with the placement of important buttons leaning to the left, right-handed participants often reacted by dragging their *"whole right arm to the other side"* (P12). Additionally, right-handed individuals preferred layouts with action buttons on the right side. One participant described this inconvenience as a clash with design conventions they have known from other displays: "*The Cart button on the upper left was very annoying because I am used to finding it in the lower right corner. It felt complicated to use this display; I didn't really like it*" (P16).

In terms of rearranging layouts in general, participants found they were not necessarily bad as long as they were quickly understandable and the task completion process remained clear; one stating: "*The usage was very intuitive. The change of language was always visible, which was helpful. It was very easy to change the items I had ordered*" (P9). Even when button placements were less

Table 3: Tukey's Post-hoc on Average Task Completion Time for Layout, Traces and Layout * Traces Conditions.

		Mean Difference	SE	df	t	p_{tukey}
Baseline	Horizontal	−2.327	0.882	618	−2.639	0.023
	Vertical	−2.135	0.882	618	−2.421	0.042
Horizontal	Vertical	0.192	0.882	618	0.218	0.974
With Traces	Without Traces	2.706	0.720	618	3.757	< .001
Baseline With Traces	Horizontal With Traces	−1.220	1.247	618	−0.978	0.925
	Vertical With Traces	−1.068	1.247	618	−0.857	0.956
	Baseline Without Traces	4.154	1.247	618	3.331	0.012
	Horizontal Without Traces	0.721	1.247	618	0.578	0.992
	Vertical Without Traces	0.953	1.247	618	0.764	0.973
Horizontal With Traces	Vertical With Traces	0.152	1.247	618	0.122	1.000
	Baseline Without Traces	5.374	1.247	618	4.309	< .001
	Horizontal Without Traces	1.941	1.247	618	1.556	0.628
	Vertical Without Traces	2.173	1.247	618	1.743	0.504
Vertical With Traces	Baseline Without Traces	5.223	1.247	618	4.188	< .001
	Horizontal Without Traces	1.789	1.247	618	1.434	0.706
	Vertical Without Traces	2.022	1.247	618	1.621	0.585
Baseline Without Traces	Horizontal Without Traces	−3.434	1.247	618	−2.753	0.067
	Vertical Without Traces	−3.201	1.247	618	−2.567	0.107
Horizontal Without Traces	Vertical Without Traces	0.233	1.247	618	0.187	1.000

Table 4: ART ANOVA - Perceived Usability

Cases	Sum of Squares	df	Mean Square	F	p	ω^2
Layout	8.83	2	4.42	14.1	< .001	0.14
Traces	3.96	1	3.96	12.65	< .001	0.06
Layout * traces	0.65	2	0.33	1.04	0.36	3.98×10^{-4}
Residuals	46.99	150	0.31			

comfortable, some participants were willing to adapt if the interaction process remained straightforward and brief. As one participant mentioned: "*While there were some preferable button placements, the interaction with the display was short and uncomplicated. Therefore, I didn't mind searching for a certain button and raising my arm a little bit more than necessary in order to finish the transaction*" (P18).

5.2.3 Hygiene. Participants saw rearranging layouts as beneficial for hygiene, (e.g., P19 states: *"[Rearranging layouts help] Not having to touch in same places as other users"*). However, they also questioned *"[...] how much unhygienic touches the rearrangement is capable of preventing"* (P18) and the traces design, as they associated them with dirt and germs. In short, some users believed rearranged layouts could help reduce contamination, but the practical impact remained uncertain. Touch traces were seen as both helpful and undesirable, depending on the user. Some participants felt usability was prioritized, stating that "*The hygiene aspect favors a rearranged layout, but for the sake of usability, a static one is better*" (P24). In contrast, others argued: "*But for hygiene, it may be a viable trade-off*" (P25).

In addition, some participants emphasized personal hygiene, saying: "*This is my first time realizing that I value hygiene more than design. Like, I know the design is opposite to my habits, but still better*" (P23). Others questioned the necessity of tackling germs on public displays, with one participant stating: "*Also, it is very normal to interact with surfaces that a lot of people have touched before. [...] Not all bacteria is bad bacteria, and also it is good for our immune system to get in touch with those dirty surfaces. We need contact to create antibodies and to strengthen it. I think trying to save oneself from 'dirt' from other people can be a step in the wrong direction*" (P2).

5.2.4 Privacy. Participants expressed concern about the privacy implications of touch traces, *"I would not want my trace being public for the next person to see"* (P13), or *"Subsequent users could reconstruct what I clicked"* (P5). In comparison, the rearrangement strategy could enhance privacy, making it harder for onlookers to track inputs (*"Rearranging layouts could provide much higher privacy, especially against social engineering attacks"*, P11). However, others contested whether rearranging layouts could truly address privacy concerns. One participant noted, "*I think that if somebody really wants to look over my shoulder, there's no real way to protect against that in the public displays* (P17). Some participants also expressed discomfort with the lingering presence of others' interactions, stating, "*I also might not want to know what the person before did on the interface*" (P13).

Table 5: Tukey's Post Hoc: Layout, Traces and Layout * Traces on Perceived Usability

		Mean Difference	SE	df	t	Cohen's d	p_{tukey}
Baseline	Horizontal	0.58	0.11	150	5.28	1.04	< .001
Baseline	Vertical	0.24	0.11	150	2.18	0.43	0.08
Horizontal	Vertical	−034	0.11	150	−3.11	−0.61	0.01
With Traces	Without Traces	−0.32	0.1	150	−3.56	−0.57	< .001
Baseline With Traces	Horizontal With Traces	0.42	0.16	150	2.72	0.76	0.08
	Vertical With races	0.14	0.16	150	0.93	0.26	0.94
	Baseline Without Traces	−0.49	0.16	150	−3.14	−0.87	0.03
	Horizontal Without Traces	0.25	0.16	150	1.61	0.45	0.59
	Vertical Without Traces	−0.15	0.16	150	−0.98	−0.27	0.92
Horizontal With Traces	Vertical With Traces	−0.28	0.16	150	−1.8	−0.5	0.47
	Baseline Without Traces	−0.91	0.16	150	−5.86	−1.63	< .001
	Horizontal Without Traces	−0.17	0.16	150	−1.12	−0.31	0.88
	Vertical Without Traces	−0.58	0.16	150	−3.71	−1.03	0.01
Vertical With Traces	Baseline Without Traces	−0.63	0.16	150	−4.07	−1.13	< .001
	Horizontal Without Traces	0.11	0.16	150	0.68	0.19	0.98
	Vertical Without Traces	−0.3	0.16	150	−1.91	−0.53	0.40
Baseline Without Traces	Horizontal Without Traces	0.74	0.16	150	4.75	1.32	< .001
	Vertical Without Traces	0.34	0.16	150	2.16	0.6	0.26
Horizontal Without Traces	Vertical Without traces	−0.4	0.16	150	−2.59	0.72	0.11

6 DISCUSSION

Our research tackles reducing smear infection risks on public touch displays by investigating GUI rearrangement strategies and visualized touch traces. In response to **RQ1**, we introduced and evaluated multiple software-based adaptation strategies to reduce (perceived) touch overlap on shared interfaces. Addressing **RQ2**, we conducted an in-depth laboratory study examining one strategy — the Rule-based Rearrangement — in combination with touch trace visualizations, assessing their impacts on perceived usability. Our findings reveal that user acceptance and perceived benefits of these interface adaptations depend on the quality of visual design, perceived hygiene improvements, and usability trade-offs. In the following sections, we critically discuss our results concerning established usability heuristics, highlighting both the potential and limitations inherent in visualized touch traces and dynamic layout rearrangements for public interfaces.

6.1 Usability of Altering Public Displays

Our quantitative and qualitative results agree on higher usability scores and faster completion times for the Baseline layout, Without Traces (**RQ2**). We included a practice round to avoid task confusion (buying groceries or drinks), familiarizing participants with this layout. Yet, the participants reported a learning effect when adapting to the other display conditions and understanding the meaning behind the touch traces. Our approach intentionally challenged usability heuristics like *Maintain Interface Consistency* and *Adhere to Standards* [47], which reflected in the usability scores but supported distributing touched areas. Furthermore, we also anticipate that the interface rearrangement would happen between interface usages in real-life contexts instead of experiencing all conditions shortly after each other, as in our study. This open point will require future exploration of how well users remember frequently used public displays, such as self-checkouts, and to what extent users would notice the rearrangement.

The inherent trade-off between the hygiene risks associated with public touch displays [1, 16, 23, 28, 41, 66] and the recognized benefits of touch-based interaction [33, 48] presents a challenge for interface design. Determining when to prioritize hygiene over usability—or vice versa—remains complex and context-dependent. In public contexts, we argue that there are clear advantages to prioritizing hygienic considerations without compromising usability. Conversely, in more private or controlled settings where touch surfaces are shared by fewer users, prioritizing usability over rigorous hygienic measures may be more acceptable. We see advantages in further exploring intelligent adaptive strategies that carefully balance hygienic improvements with usability, rather than sacrificing one for the other.

An alternative strategy to ours might involve targeted adaptations based on user characteristics, such as handedness. Previous research has demonstrated that accounting for handedness can significantly enhance user comfort and interaction efficiency [69], while simultaneously distributing interaction across the interface. Although assessing handedness would require an additional interaction step, this approach could prove beneficial, especially in public touch display contexts. Currently, the adaptation of touch interfaces based on handedness is relatively unexplored compared to research on mobile phone usage [57, 69] or gesture-based interactions [19]. Given our participants' strong preferences for using their dominant hand, even when primary interface elements appeared inconveniently located, exploring handedness-driven strategies presents a promising direction for future research to reduce smear infection risks and enhance usability.

6.2 Hygienic Touch Traces for a More Informed User Behavior

Contrary to prior work [36, 56], our results showed that visualized touch traces were rather perceived as disturbing, and participants mainly preferred the Without Traces condition. Yet, we also saw a similar willingness to adapt the interaction behavior as a reaction to the traces visualizations as in Hirsch et al. [26], which contributes to reducing touch overlaps on public displays (**RQ1**). Furthermore, we assume that participants' slower task completion time in conditions With Traces compared to those Without Traces derives from facing an additional cognitive load as users must interpret and respond to the additional trace visualizations. However, participants reported a learning effect, suggesting they could adapt faster over time. This indicates that users might get sufficiently familiar with quickly adapting their interaction while benefiting from the additional on-screen information over time and use. Yet, the effort and the decision to integrate touch trace visualization should be made depending on the context and purpose.

In addition, participants critically commented on the trace design, which we based on prior work's findings [36]. However, our results suggest that a different visual design, such as using more abstract visualization cues, might elicit less discomfort. Ongoing research in information visualization explains that schematic, more realistic visualizations can be better in learning contexts, but confirms that simpler, abstract shapes are easier to grasp [60, 61]. Thus, future work should test the impact of different touch trace visualizations on public touch display task completion time and understandability to optimize usability.

Lastly, some participants viewed touch traces as helpful guides to identify cleaner areas, highlighting the usability trade-off: some participants valued the hygienic benefits of the adaptations, while others found the changes disruptive. Offering control, such as making touch trace visibility and layout rearrangement optional, may better balance hygiene and usability. Some participants speculated that layout rearrangements might pose usability challenges for certain groups, such as older adults or users relying on pattern recognition, pointing out an important avenue for future research. Investigating whether an opt-in model improves user acceptance and usability could help accommodate individual preferences. Future studies should investigate how this optionality affects user acceptance, satisfaction, and experience, providing valuable insights to enhance public touch displays.

6.3 Rearranging Display to Increase Security

While our study did not assess the security implications of the explored approaches, adaptive screen layouts could potentially reduce the risk of 'shoulder surfing' attacks, as discussed by Schneegass et al. [59]. However, visualizing touch traces could increase such risks, particularly in sensitive contexts like entering a personal identification number or other private information, as highlighted in prior research on usable security [3, 9, 15]. Alternating the layout may also exacerbate shoulder surfing, as recalling input from memory is more challenging than recognition [5, 25], which an adaptive screen would require. Future research could investigate how adaptive layouts affect security, particularly in high-stakes contexts, such as entering sensitive information like PINs.

6.4 Limitations and Future Work

Our study was conducted under controlled lab conditions, limiting its real-world applicability. We tested with a specific interface for snacks and drinks, which may not generalize to other websites or interfaces. Our results focus on perceived rather than actual touch overlap reductions. Future work should refine the setup and include quantitative measurements in real-world settings. Also, our setup was further limited by the display choice. Tablet or other screen sizes could impact the results, such as, for example, the likability of displayed touch traces as presented in Mäkelä et al. [36]. At the same time, our diverging results provide grounds for further discussion and research potential. Moreover, our sample consisted primarily of young adults (19 to 32 years, median = 25), with most participants being university students from computer science-related fields. All participants had prior experience with touch-based public displays. These factors limit the generalizability to older adults and individuals less familiar with interactive displays. Future research should address these biases to improve applicability and test with a broader demographic.

7 CONCLUSION

Our study examined software-based adaptations to reduce smear infection risks on public touch displays through GUI rearrangements and visualized touch traces. We assessed the Rule-based strategy and its potential to reduce perceived touch overlap while balancing usability, privacy, and hygiene in a three-times-two within-subject lab study (N=26). Our findings suggest that software-based adaptations can reduce touch overlap but introduce usability trade-offs. Though reducing overlap, they increase distraction, highlighting the hygiene-usability balance challenge. This underscores the need for designs that allow for user control, address diverse hygiene perceptions, and potentially further consider privacy concerns, ensuring that these features are implemented in ways that optimize both functionality and user experience. In sum, our work highlights the complex balance between the need for enhanced hygiene on public touch displays and core principles of usability and user experience. While digital adaptations promise to reduce touch overlap, their effective implementation depends on prioritizing user agency through customizable options. Moving forward, the field should adopt comprehensive research approaches that integrate real-world evaluations, consider the diverse needs and preferences of all user groups, and deepen our understanding of how users perceive and interact with these technologies to unlock the full potential of safer, more user-friendly public touch displays.

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8 APPENDIX

9 PRE-STUDY QUESTIONNAIRE

9.1 Demographic

(1) What gender do you most identify with?
(2) When were you born?
(3) What is your highest educational degree?
(4) What is your current main occupation?
(5) How often do you use public displays (e.g., self-checkout in the supermarket, fast food counter, ticket machines)? (daily, at least once a week, at least once a month, less than once a month, never)

9.2 Hygiene Awareness and Safety Perception

(1) When interacting with public displays, I think about the possible hygiene risks associated with touching surfaces that are shared with other people.
(2) In general, I feel comfortable using public touch displays despite the possible hygiene risks.
(3) When interacting with public displays, I think of other people around me potentially observing my input on the screen.
(4) In general, I feel comfortable using public touch displays despite the possibility of others observing my interaction.

10 INTERIM QUESTIONNAIRE

10.1 UX / Usability via Hedonic TAM

Each question was rated using a 7-point Likert scale (strongly disagree to strongly agree) unless noted otherwise.

10.1.1 *Perceived usefulness.*

(1) By using the touch display… I can decide more quickly and more easily what I want to buy than in the past.
(2) I can better decide what I want to buy than in the past.
(3) I am better informed about the purchases with this display.
(4) I can decide more quickly and more easily whether I want to buy a particular product or not.

10.1.2 *Perceived ease of use.*

(1) The interaction with the display is clear and understandable.
(2) The interaction with the display does not require a lot of mental effort.
(3) I find the display easy to use.
(4) I find the display easy to get to do what I want it to do.

10.1.3 *Perceived enjoyment.* *Each question was rated using a 7-point semantic differential scale.*

(1) Enjoyable–disgusting
(2) Exciting–dull
(3) Pleasant–unpleasant
(4) Interesting–boring

10.1.4 *Behavioral intention.*

(1) I would reuse the display.
(2) I predict that I would reuse it in the short term.

10.2 Qualitative Statements

(1) Any comments about your latest interaction experience?

11 FINAL QUESTIONNAIRE

11.1 Scaling questions

(1) I would prefer to interact with non-adapting public displays compared to an adjusting one.
(2) I would prefer to have public displays adjust themselves compared to non-adapting ones.
(3) I think that adjusting the interface between users increases the display's hygiene.
(4) I think that adjusting the interface between users increases the users' privacy.
(5) I think that adjusting public displays between uses has a negative effect on their usability.
(6) I would like to see more public displays adjust themselves between users.
Please explain why: ______________________________
(7) I would prefer to interact with adapting public displays that highlight previous users' traces.
Please explain why: ______________________________
(8) Layout adjustments to public displays between uses do not bother me.
Please explain why: ______________________________
(9) Layout adjustment to public displays between uses would make me more comfortable while interacting with them.
Please explain why: ______________________________

11.2 Qualitative Feedback / Open questions

(1) Please describe if/how the traces from previous users influenced your behavior.
____
(2) Please describe your perceived feeling of comfort to interact with the display when seeing previous users' traces.
____