Quadratic Survey Interface

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This study explores the design of interactive interfaces for Quadratic Surveys (QS) that employ Quadratic Voting (QV) mechanisms [1], enhancing collective decision-making in areas such as societal resource allocation and design decisions [2]. Prior work shows that survey interface design significantly influences results and accuracy [**<empty citation>**]. We propose a two-phase "organize-then-vote" interactive interface to reduce cognitive load in both short and long QS. Through a 2x2 between-subject in-lab study, we compared this novel interface with a traditional text interface across different option lengths. We found that, although cognitive loads were similar on paper, our interactive interface prevented participants from satisficing due to cognitive overload in long QS conditions. We also noted significant improvements in decision-making quality and more comprehensive considerations when participants expressed their opinions on QS. This research contributes to CSCW by demonstrating how digital interface design can support more effective collaborative attitude elicitation tools in societal decision-making contexts.

CCS Concepts: • **Human-centered computing → Empirical studies in collaborative and social computing**; **Collaborative and social computing design and evaluation methods**; *HCI design and evaluation methods*.

Additional Key Words and Phrases: Quadratic Voting; Likert scale; Empirical studies; Collective decision-making

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1 Introduction

Surveys are a ubiquitous tool for collective decision-making problems. Fundamentally, surveys allow decision-makers to aggregate the opinions of crowds. States utilize referendums to form policy decisions; organizations such as Pew Research Center in the United States deploy surveys to identify public perspectives on societal challenges; and city council meetings provide public forums where community members can voice their concerns and foster consensus. However, to ensure that the signals decision-makers receive are high quality, it is imperative that survey tools accurately capture the attitudes of survey-takers. In the domains of Computer-Supported Collaborative Work (CSCW) and Human-Computer Interaction (HCI), researchers have explored novel surveying methods that involved rating and ranking of attitudes to gather data and understand collaborative behaviors which informs decisions [3, 4, 5].

Quadratic Surveys (QS) have arisen as a promising new survey tool for eliciting survey-taker preferences out of a list of items. In this paper, we define **Quadratic Surveys (QS)** as a surveying tool that employs the quadratic mechanism [6]. In QS, participants are given a fixed budget of credits to spend on votes indicating support or opposition for each item. Purchasing k votes for an option in QS expends k^2 credits. Because participants are able to allocate multiple votes for or against a particular item, QS fundamentally asks participants to both rank (determine a

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relative preference) and rate (determine strength of preference) survey items. A recent study in CSCW research demonstrated the benefits of using QS over traditional Likert-scale surveys – it more accurately reflects individual preferences because the fixed budget forces survey-takers to make trade-offs between different survey items [2]. Quadratic Surveys, referred to as Quadratic Voting when used for voting, have been deployed in the wild, both in the public [7, 8] and private sectors [9]. Despite the promise of QS, however, its complexity has limited its practical use. QS takes significantly longer for survey-takers to complete than a corresponding Likert-scale survey, likely due to the difficulties of reasoning around the quadratic vote cost and tradeoff-thinking induced by QS.

The design of attitude-capturing tools is critical as it significantly affects how individuals express their attitudes [10, 11, 12, 13, 14, 15, 16]. Better digital interfaces yield higher quality responses, leading to more accurate and reliable collective decision-making. Identifying challenges faced by survey respondents is crucial for improving effectiveness. As Quadratic Surveys inherently produce higher quality responses, the interface should facilitate, not obstruct, this advantageous outcome. Therefore, we ask: *How can we design interactive interfaces to support participants in completing Quadratic Surveys?*

QS interfaces should help navigate participants in completing the survey due to the congitive load that imposed on them. First, QS requires respondents to construct preferences, a mentally demanding task. Second, QS respondents must express preferences numerically, forcing trade-offs under a budget. Since QS adopts the QV mechanism and there are no existing studies on QV interfaces, we turn to preference ocnstruction literature to inform our interface design. As Lichtenstein and Slovic [17] note, individuals construct preferences in situ when preferences are undefined, necessitating trade-offs or quantifying opinions. Svenson [18] theorized individuals differentiate among options before consolidating a result. We explored ranking, selection, and organization approaches over three design iterations to facilitate preference construction. During our iteration, we learn that survey respondents need not construct a full set of preferences among all options to allocate their credits when completing QS. We then consulted survey response format literature[19] to inform our design componenets and included a drag-and-drop for direct interface manipulation for survey respondents.

Finally, we introduce a novel interactive QS interface (Figure 6) that nudges QS survey respondents to take a two-step 'organize-then-vote' approach to preference construction and elicitation. The final interface aimed to scaffold the 'differentiation and construction' decision-making process from decision making research, supporting the preference construction journey through a two-step approach: first organizing, then voting. Participants are showed all options on the survey one-at-a-time, and guided to categorize them into a three-tiered preference category. Participants can organize their thoughts within the bins as they wish. These categories then inform the position of the voting interface, where survey respondents finally expresses their preferences.

Other then cognitive load imposed from the mechanism itself, long lists of options can cause cognitive overload. Empirical use of QV implementations, such as the Colorado House of Representatives, considered 107 bills in one QV event [20]. Psychology literature showed that too many choices can lead to challenges like choice overload and overchoice [21, 22]. Increased choices raise cognitive load, leading to more survey response errors and 'good enough' answers instead of optimal ones [23, 24]. Reducing the number of options can be impractical if the goal is to elicit fine-grained individual preferences for decision makers. This practical challenge addes additional cognitive load challenges to using QS.

With our proposed interface, considering practical use of QS, this research examines the influence of interactive interfaces on QS with varying option lengths. We seek to answer the following research questions:

- RQ1. How does the number of options in QS impact respondents' cognitive load?
- RQ2a. How does the two-phase interactive interface impact respondents' cognitive load compared to a text interface?
- RQ2b. What are the similarities and differences in sources of cognitive load across the two interfaces?
- RQ3. What are the differences in QS respondents' behaviors when coping with long lists of options across the two-phase interactive interface and the text interface?

To answer these research questions, we designed a 2x2 between-subject in-lab study. Participants completed a QS with either a short or long list of options using our designed text or interactive interface. We measured participants' cognitive load using NASA-TLX and conducted interviews focusing on its different elements. We collected clickstream data as participants completed the QS. We recruited 41 participants from a local community and surveyed their attitudes on various societal issues. We analyzed study results, transcribed, coded, and thematically analyzed interviews.

Contributions. We contributed to CSCW by proposing the first interactive interface specifically designed for QS and QV-like applications. No prior research has investigated interfaces for QS, especially long ones that lead to cognitive overload. Our two-stage organize-then-vote interface facilitates critical decision making and limits satisficing behaviors. This design promotes incremental updates and deeper engagement, enhancing understanding and decision quality. Second, we conducted the first in-depth qualitative analysis identifying key factors contributing to cognitive load among survey respondents. Our qualitative interviews identified design challenges for QS, driving further research directions.

The remainder of this paper is structured as follows: related works are covered in section 2, followed by design decisions for the interactive QS interface 3. Section 4 details the experiment design. Study findings are presented in sections 5, section 6. We discuss our findings and future work in section 7.

2 Related works

This research sits at the intersection of three core areas: quadratic surveys, survey and voting interface design, and choice overload and its cognitive challenges. In this section, we review related works in each of these areas.

2.1 Quadratic Survey and the Quadratic Mechanism

We introduce the term **Quadratic Survey (QS)** to describe surveys that use the Quadratic Mechanism to collect individual attitudes. The **Quadratic Mechanism** is a theoretical framework designed to encourage truthful revelation of individual preferences through a quadratic cost function [6]. the use of Quadratic Voting (QV) techniques in surveys to collect individual attitudes. As Quarfoot et al. [25] demonstrated, QV effectively gauges public opinions. Unlike traditional surveys that elicit either rankings *or* ratings, QS allows detailed presentations of *both* by casting multiple votes for or against options, incurring a quadratic cost. Cheng et al. [2] showed that this mechanism aligns individual preferences more accurately with their behaviors than Likert Scale surveys, especially in resource-constrained scenarios.

The concept of QS is rooted in This framework gained popularity through **Quadratic Voting (QV)**, also known as plural voting, which uses a quadratic cost function in a voting framework to facilitate collective decision-making [26]. While QV mitigates the tyranny of the majority in traditional voting systems, QS adapts these strengths to encourage truthful preference expression in surveys. QV is not subject to Arrow's impossibility theorem, which states that no voting system can perfectly aggregate individual preferences without trade-offs [27], because it does not require aggregating rankings.

To illustrate how QS works, we formally define the mechanism as follows: Each survey respondent is allocated a fixed budget, denoted as B, to distribute among various options. Participants can cast n votes for or against each option k. The cost c_k for each option k is derived as:

$$c_k = n_k^2 \quad \text{where} \quad n_k \in \mathbb{Z}$$

The total cost of all votes must not exceed the participant's budget:

$$\sum_k c_k \leq B$$

Survey results are determined by summing the total votes for each option:

$$\text{Total Votes for Option } k = \sum_{i=1}^{S} n_{i,k}$$

where S is the total number of participants, and $n_{i,k}$ is the number of votes cast by participant i for option k. Each additional vote for each option increases the marginal cost linearly, encouraging participants to vote proportionally to their level of concern for an issue [1].

In recent years, empirical studies on QV have expanded to different domains [28, 29]. Applications based on the quadratic mechanism have also grown, such as Quadratic Funding, which redistributes funds based on outcomes from consensus made using the quadratic mechanism [30, 31]. Recent work by South et al. [32] applies the quadratic mechanism to networked authority management, later used in Gov4git [9]. However, despite the growth in depth and breath of applications using the quadratic mechanism, little attention has been given to the user experience and interface design that support individuals in expressing their preference intensity.

2.2 Survey, Questionnaire, and Voting Design

The relative lack of research in quadratic mechanism and QS interface design is concerning, as prior research in survey and questionnaire interfaces demonstrated substantial impact on the response and individual's experience on even seemingly minor design decisions.

Research in the marketing and research community studying survey and questionnaire design, usability, and interactions focuses on understanding the infuence of styles and question presentation, or 'Response Format,' of a survey or questionnaire. Weijters et al. [33] demonstrated that horizontal distances between options are more influential than vertical distances, with the latter recommended for reduced bias. Slider bars, which operate on a drag-and-drop principle, show lower mean scores and higher nonresponse rates compared to buttons, indicating they are more prone to bias and difficult to use. In contrast, visual analogue scales that operate on a point-and-click principle perform better [19] These research highlighted outcomes are influenced by the different designs.

Given that voting, similiar to surveys and questionnaires are designed to elicit individual choices, we turn to voting interface literature. Voting interfaces can have an even more substantial influence on behaviors and outcomes.The notorious butterfly ballot [34] is one example of this – Wand et al. [34] argue that an atypical ballot design may have caused enough accidental votes to swing the 2000 U.S. Presidential Election. Researchers like Engstrom and Roberts [10], Chisnell [35], and organizations like the Center for Civic Design, which publishes reports like "Designing Usable Ballots" [36], stress the importance of interface design and how it can influence democratic processes. We group this literature into three main categories: designs that shifted voter decisions, designs that influenced human errors, and designs that incorporated technologies to improve usability.

Designs that shifted voter decisions: For example, states without the option for straight-party ticket voting (the option to circle an option that votes for all the candidates in the same party) exhibited higher rates of split-ticket voting [10]. Another example from the Australian ballot with an office block and no party box (having a box that clearly segments the position that the candidates are competing for) has been shown to enhance incumbency advantages.

Designs that influenced errors: Butterfly ballots increased voter errors because voters could not correctly identify the punch hole on the ballot. Splitting contestants across columns increases the chance for voters to overvote [37]. On the other hand, Everett et al. [38] showed the use of incorporating physical voting behaviors, like lever voting, into GUI interfaces.

Designs that incorporated technologies: Other projects like the Caltech-MIT Voting Technology Project have sparked research to address accessibility challenges, resulting in innovations like EZ Ballot [39], Anywhere Ballot [40], and Prime III [41]. In addition, Gilbert et al. [42] investigated optimal touchpoints on voting interfaces, and Conrad et al. [43] examined zoomable voting interfaces.

While the design of voting systems and question response format markedly influence voter behavior and decision accuracy, these interface elements also directly impact the cognitive load on users. An effective design would enhance usability and reduce cognitive challenges faced by survey respondents, especially in complex response mechanisms like QS.

2.3 Cognitive Challenges and Choice Overload

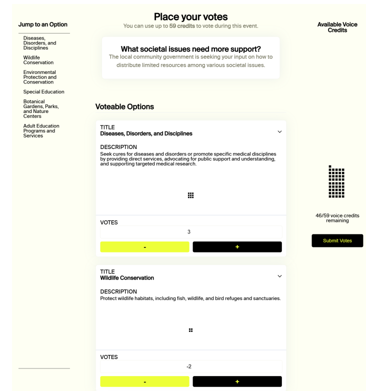
Despite the deep insight prior research learned about voting and surveying techniques and the robust mechanism demonstrated in theoretical applications of quadratic mechanisms, the inherent challenge that survey respondents are required to make many difficult decisions poses a unique cognitive challenge that no prior literature has tackled. Lichtenstein and Slovic [17] laid out the three key elements that make decisions difficult. They include people making decisions within an unfamiliar context, people forced to make tradeoffs due to conflicts among choices, and people quantifying values for their opinions. QS fits into the description of all three elements, as participants can face options placed by the decision maker which they have never seen before. Participants are bounded by budgets that force them to make tradeoffs, and the final votes are presented in values. Hence, we believe that QS introduces a high cognitive load.

Daniel [44] demonstrated that cognitive overload can adversely affect performance, for instance, causing individuals to rely more on heuristics rather than engaging in deliberate and logical decision-making. In addition, some researchers believe that preferences are constructed in situ just as memories are. Thus, when too much information is presented to an individual, they can 'satisfice' their decisions [45, 46, 47]. This behavior refers to when an individual settles on a 'good enough' solution rather than 'optimal' response. This overload can happen because of the presence of too many options. Subsequently, too many options can lead to individuals feeling overloaded, leading to decision paralysis, demotivation, and dissatisfaction [21].

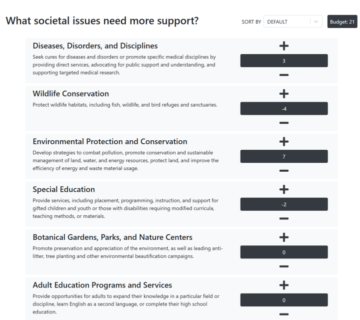
Additionally, Alwin and Krosnick [48] highlighted that the use of ranking techniques in surveys can be time-consuming and potentially more costly to administer. These challenges are compounded when there are numerous items to rank, requiring substantial cognitive sophistication and concentration from survey respondents [49].

However, in several notable applications of Quadratic Voting in society, there can be hundreds of options within a single QV question. For instance, the 2019 Colorado House of Representatives considered 107 bills [50], and the 2019 Taiwan Presidential Hackathon featured 136 proposals [51]. These psychological and behavioral research highlighted the importance of understanding how individuals navigate and can potentially benefit from interfaces under long-list QS conditions.

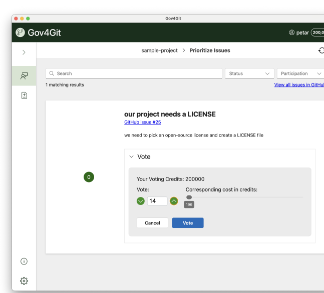
(a) Software by WeDesign, used in the first empirical QV research [25]. Little information is available about the software, except for an image from [1]. In the image, each prompt has thumbs up and down icons to update the vote in the center. The remaining budget appears as a progress bar at the top.



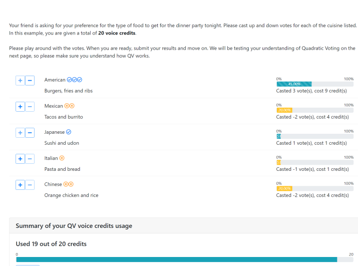
(b) An open-sourced QV interface [52] forked from GitCoin [53], used by the RadicalxChange community [54]. This interface presents total credits as small blocks. Votes are updated using plus and minus buttons, with numerical counts shown under each option and surface area as costs.



(c) An open-source QV interface [55] offers a publicly available service. Options show only the current number of votes, with credits displayed in the top right corner. This interface does not show the costs of votes but supports sorting options.



(d) The interface designed for gov4git [9] updates votes using arrows under each option, with the associated cost shown as a percentage bar to the right. A search bar exists for searching specific pull requests or issues.



(e) The interface used in the research by Cheng et al. [2] employs the most visual components. Icons depict the current number of votes, with progress bars signifying the current spending.

Fig. 1. Recent interface implementations for applications using quadratic mechanism.

3 Interface Design

Since there are no prior studies and standard interfaces for tools using the quadratic mechanism, we designed, iterated, and developed an interactive interface for QS based on the prior literature and multiple iterations. In this section, we first describe the iterative prototyping process, detail the final design of the interactive interface, and finally, present the text-based interface designed for comparison in this study.

3.1 QV applications interfaces in the wild and early paper prototypes

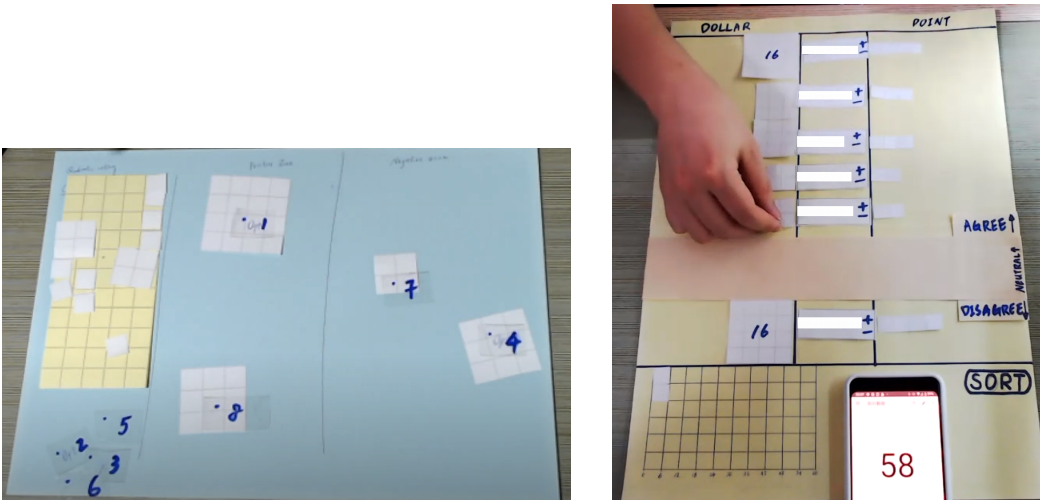
Since QS builds upon the QV mechanism, we being our design iteration based on existing QV applications in the wild. For coherence and brevity, we chose not to describe the paper prototype iteration in depth given it's exploratory nature and provide it in the Appendix with other alternative design considerations in Appendix A.

Existing interfaces consists standardlized componenets shown in Figure 1 [1]. All interfaces shared these key components:

- Option list: A list of options contesting for votes.
- Vote controls: Buttons to increase and decrease votes associated with each option.
- Individual vote tally: A representation of votes associated with an option.
- Summary: An auto-generated summary of costs and remaining budget.

Most components were focused on presenting information and obtaining votes, only the summary addressed budget constraints. During our initial paper prototyping interations (Figure 2), we tested different presentations of these compoenents with added features to assist information organization. Pretest respondents felt QS challenging due to idenfitying relative preferences among options and deciding the degree of trade-offs between options. In this study, we focus on the first challenge to inform our interface design iterations.

[1]Figure 1d did not exist until the writing of this paper.



(a) In this paper prototype, issues are denoted by different numbers that appear on mouseover. Pretest respondents can move options anywhere in the two sections of the interface, one denoting positive and one negative. The blocks represent the cost for each option, with no indication of the number of current votes. The credits are shown in the yellow box on the left.

(b) This paper prototype separates the positive and negative areas with a 'band' at the center. Undecided options are placed inside this band. The cost and the votes on both sides of the interface are denoted by small blocks. The budget is shown in the yellow box below the interface with a numerical counter.

Fig. 2. Initial paper prototypes designed for QS interface

3.1.1 Prototype 1: Ranking-Vote. Considering that relative preference is often through ranking items, we tested whether ranking options before voting would help establish individual's relative preference in our prototype 1. This prototype allowed respondents to reposition options before voting. Pretests revealed that respondents rarely moved the options and questioned the necessity of full ranking, as it did not influence their QS submission. Additionally, many were unaware that options were draggable until shown. This insight indicates that full ranking is unnecessary for establishing relative preferences. Therefore, we decided to ask respondents select a subset of options instead of requiring a full rank among all options.

3.1.2 Prototype 2: Select-then-Vote. Based on feedback from Prototype 1, instead of *allowing* individuals to rank options, prototype 2 implemented a two-phase process that *intentionally* select options to express opinions before voting. As shown in Figure 4, survey respondents selected their preferred options (Figure 4a), and the interface positioned these options at the top of the list for voting (Figure 4b). We identified several issues during prototype 2 pretest: many respondents marked most options as 'options they care about,' which undermined the design's purpose. Additionally, the lack of clear distinction between selected and unselected options confused respondents about the necessity of Step 1. Thus, we need a clearer distinction and connection between the two phases to effectively construct relative preferences.

3.1.3 Prototype 3: Organize-then-Vote. Figure 5 shows the last prototype where we built on the previous takeaway by providing finer-grain groupings and creating a clear connection between option organization and voting position. Specifically, we provided three categories: Positive, Negative, and Neutral. Initially, respondents see all options under the section labeled 'I don't know,'

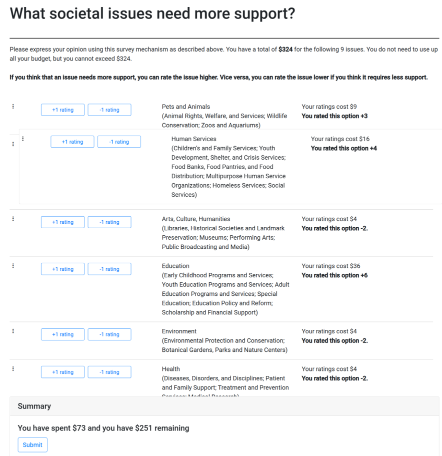
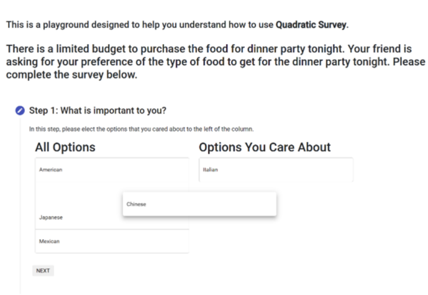


Fig. 3. A Ranking-Vote Prototype: Each option is draggable to position in a specific location amongst the full list of options. Votes can be updated using the buttons to the right of the interface with vote count and costs to the right of the interface. A summary box is placed sticky to the bottom of the screen.



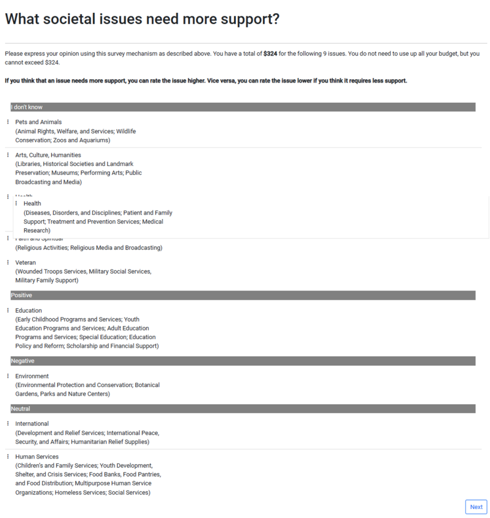
(a) Options are drag and dropped to the 'Option You Care About' box.

(b) The previous step collapses showing all voting options.

Fig. 4. A Select-then-Vote Prototype: This prototype introduces a two-step voting process. As shown in Fig. 4a, the first step involves selecting options for further consideration. Important options are placed at the top of the list for voting shown in Fig. 4b, but options can be placed anywhere on the list if desired. The rest of the controls remain the same as the previous prototype.

which includes only the option descriptions. We ask respondents to move these options into the categories below. Voting controls and information appear on each option once respondents move to the subsequent page, forming a clear connection between option groups, positions, and voting controls.

Feedback indicated that survey respondents are comfortable with the two-phase organize-then-vote design, demonstrating it as a central strategy for our interface development. However,



(a) The Organization Interface: Options are shown initially in the first bin labeled as 'I don't know.' Survey respondents can then drag and drop these options into the latter bins: Positive, Neutral, or Negative. On this interface, only the details of each option are shown.

(b) The Voting Interface: Voting controls appear on the left side of each option, showing the current votes and associated costs on the right. A budget summary is stuck at the bottom of the screen.

Fig. 5. Organize-then-Vote Prototype: Survey respondents first organize their thoughts into categories, then vote on the options.

several areas for enhancement were identified: First, the dragging and dropping mechanism in the organization phase is cumbersome and may inadvertently suggest a ranking process, contrary to our intentions. Second, placing unorganized options at the top of the voting list is counterintuitive. Third, the voting controls are disconnected from the option summaries, dividing attention between the left and right sides of the screen. These insights guided refinements in the final interactive interface, adhering to the two-phase organize-then-vote design framework.

3.2 Finalizing the Interactive Interface

In the previous subsection, we highlighted critical prototype iterations that informed the final two-phase interactive process that defines the user journey. We now present the final interactive interface, its operations, and the supporting literature for comprehensive understanding. Then, We also discuss the aesthetic design choices that emerged throughout the iterations.

3.2.1 Justifying a two-phase approach. Recall the ultimate objective of the interactive interface is to facilitate preference construction and reduce cognitive load. The interactive interface, shown in Figure 6 consists of two steps: An organization phase and a voting phase. Throughout both phases, survey respondents can drag-and-drop options across the presented option list.

A two-phase approach. If preferences are constructed, by nature, they consist of a series of constructed decision-making processes [17]. Two major decision-making theories informed the design decision of a two-step interaction interface design: Montgomery [56]'s Search for a Dominance Structure Theory (Dominance Theory) and Svenson [18]'s Differentiation and Consolidation Theory

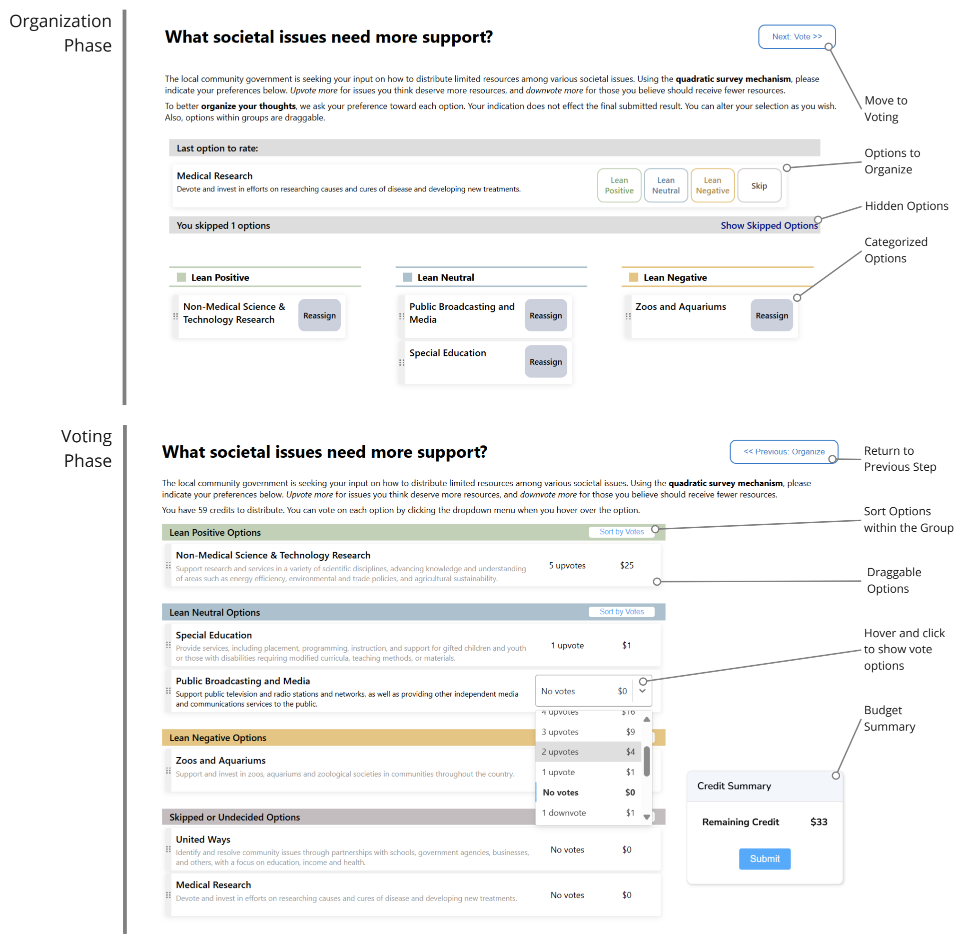


Fig. 6. The Interactive Interface: The interface consists of two phases. Survey respondents can navigate between phases using the top right button. In the organization phase, respondents will be presented with one option at a time where they can choose among four choices: Lean Positive, Lean Neutral, Lean Negative, or Skip. Skipped options are hidden and can be evaluated later. Options that are chosen will be listed below. Items can be dragged and dropped across categories or returned to the stack. In the voting phase, options are listed in the order of the four categories. When hovering over each option, respondents can select a vote for that option using the dropdown. Each dropdown contains the cost associated with the vote. A sort button allows ascending sorting within each category. A summary box tracks the remaining credit balance.

(Diff-Con Theory). The former suggested that decision-makers prioritize creating dominant choices to minimize cognitive effort by focusing on evidently superior options [56]. The latter described a two-phase process where decisions are formed by initially *differentiating* among alternatives and then *consolidating* these distinctions to form a stable preference [18]. Both theories echoed the design decision in building the interactive experience to reduce initial decision dimensions and the mental procedures involved in emphasizing relatively important options and forming decisions.

Hence, the two-phase design – organize then vote – aimed to facilitate this cognitive journey explicitly. The first phase focused on differentiating and identifying dominant options, enabling survey respondents to preliminarily categorize and prioritize their choices. The second phase presented these categorized options in a comparable manner, with drag-and-drop functionality, enhancing one's ability to consolidate preferences. This structured approach aimed to construct a clear decision-making procedure that reduced cognitive load and enhanced clarity and confidence in the decisions made.

Phase 1: Organization Phase. The goal of the organization phase was to support participants in identifying dominating options or partitioning options into differentiable groups. In this section, we first describe how the interaction worked, then we detail reasons for the different design decisions implemented.

The organizing interface, depicted on the top half of Figure 6, sequentially presented each survey option. Participants selected a response among three ordinal categories – lean positive, lean negative, or lean neutral. Once selected, the system moved that option to the respective category. Participants could skip the option if they did not want to indicate a preference. Options within the groups were draggable and rearrangeable to other groups should the participants wish.

Strack and Martin [57]'s research showed that upon understanding a survey question, respondents either recalled a prior judgment or constructed a new one when completing an attitude survey. In addition, revealing one option at a time gated the amount of information presented to the survey respondent and thereby reduced the extraneous load [58]. This process allowed participants to form or express opinions on individual options incrementally. This design also mitigated the original concern from prototype 3 where participants accidentally treated the organizing task as a ranking task.

The three possible options, positive, neutral, and negative, aimed to scaffold participants in constructing their own choice architecture [59, 60], which strategically segmented options into diverse and alternative choice presentations while avoiding the biases from defaults. We believed that these three categories were sufficient for participants to segment the options. However, we chose not to limit the number of options one could place into a category to prevent restricting user agency, a core user interface design principle [61].

Immediate feedback displaying the placement of options and allowing participants to rearrange them via drag-and-drop adhered to key interface design principles [61]. At the same time, it allowed finer grain control for individuals to surface dominating options and create differentiating groups of options.

Phase 2: Interactive Voting Phase. The objective of the voting phase was to facilitate the consolidation of differentiated options through interactive elements while reinforcing the differentiation across options constructed by participants from the previous phase. This facilitation was achieved by retaining the drag-and-drop functionality for direct manipulation of position and enabling sorting within each category.

Options were displayed as they were categorized within each category from the previous step and in the following section orders – lean positive, lean neutral, lean negative, and skipped or undecided as detailed on the bottom half of Figure 6. The Skipped or Undecided category contained options left in the organization queue, possibly because survey respondents had a pre-existing preference or chose not to organize their thoughts further. The original order within these categories was preserved to maintain and reinforce the differentiated options. This new ordering sequence mitigated the concern from prototype 3 where options without a category are left at the top of the voting interface. Respondents had the flexibility to return to the organization interface at any point during the survey to revise their choices.

In the interactive interface, options remained draggable, enabling participants to modify or reinforce their preference decisions as needed. Each category featured a sort-by-vote function that enabled reordering within the same category. Although these interactions did not influence the final voting outcome, they were designed to support consolidation and positional proximity in information organization. This design aimed to automate the grouping of similar options while providing an intuitive drag-and-drop mechanism, thereby facilitating decision-making by placing similar options near each other. This echoed the principles of the proximity compatibility principle, particularly emphasizing spatial proximity and mental compatibility [62]. The interface design anticipated that participants would find it easier to consolidate their choices when similar options were positioned close together, thereby reducing cognitive load.

While multiple interaction mechanisms exist, drag-and-drop has been extensively explored in rank-based surveys. For instance, Krosnick et al. [63] demonstrated that replacing drag-and-drop with traditional number-filling rank-based questions improved participants' satisfaction with little trade-off in their time. Similarly, Timbrook [64] found that integrating drag-and-drop into the ranking process, despite potentially reducing outcome stability, was justified by the increased satisfaction and ease of use reported by respondents. The trade-off was deemed worthwhile as QS did not use the final position of options as part of the outcome if it significantly enhanced user satisfaction and usability [65].

Together, these design decisions led to our belief that a two-step interactive interface with direct interface manipulation could reduce the cognitive load for survey respondents to form preference decisions when completing QS.

3.2.2 Aesthetic Design Decisions. There are three aesthetic design decisions that made it to the final interface. First, we decided to remove all visual elements. Prior literature suggested that the use of emojis might influence the interpretations of surveys [66] and decrease user satisfaction [13]. Prior literature also noted that not all data visualization elements reduce cognitive demand [67]. Even though effective visualization can aid decision-making, it remains an open question that this study does not aim to address, thus we also removed all visualization elements such as blocks, progress bars, and percentage indicators.

Second, the final interface has all options presented on the screen at the same time, intentionally. Unlike all the prototypes and existing interfaces, prior literature emphasized the importance of placing all the options on the same digital ballot screen to avoid losing votes. This echoes the proverb "out of sight, out of mind," where individuals might be biased toward options that are shown to them, and additional effort is required for individuals to retrieve specific information if options are hidden.

Last, we decided to use a dropdown positioned to the right of the option such that control of votes and the budget summary are placed near one another. The layout of the votes and cost was inspired by online shopping cart checkout interfaces where quantities are supplied next to the itemized costs followed by the total checkout amount. We chose a dropdown after iterating with two alternative input methods (Figure 7): the original click-based buttons and a wheel-based implementation. The former design requires survey respondents to click multiple times to reach their desired vote values. Thus, we wanted to look for a solution to aid respondents in reaching their intended value faster. A wheel-based approach allows intuitive control of the votes by using the wheel on the mouse and clicking to fine-tune the values. However, in our early pilot studies, not all participants were familiar with wheel control, thus we opted for a dropdown menu for vote selection.

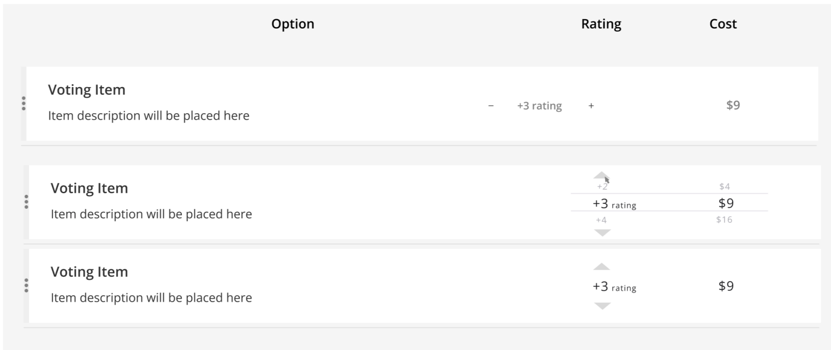


Fig. 7. The click-based and wheel-based designs for vote control included: The former mirrors traditional vote control used in other quadratic voting interfaces, where each click represents an increase in votes. The latter allows control through both clicks and mouse wheel rotation.

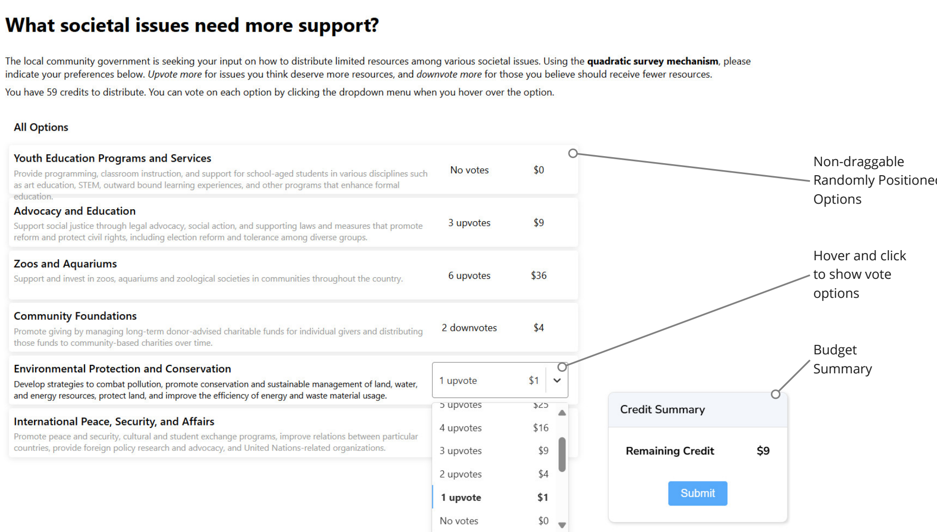


Fig. 8. The text-based interface: This interface is based on the interactive version but does not include the two-phase interactive support and lacks the drag-and-drop functionality. Options are randomly positioned.

3.3 Text-based Interface

To study how the interactive components influenced participants' cognitive load and behavior, we removed the two-phase interactive design and the drag-and-drop features for the text-based interface. The text-based interface shares the other functionalities of the interactive interface, as shown in Figure 8. The interface contained the question prompt at the top of the screen. The options were presented in a list underneath the prompt. Survey respondents could update the votes by selecting from a dropdown that provided all possible voting options and costs given the number of credits available. A small summary box to the right of the interface showed the current total cost and the remaining credits for the respondent. The interface randomly presented options to avoid ordering bias [68, 69].

Both experiment interfaces are developed with a React.js frontend and a Next.js backend powered on MongoDB. Both services were open-sourced [2].

4 Experiment Design

In this section, we detail the overall experiment design and explain the reasoning behind specific experiment decisions.

4.1 Experiment Protocol

We recruited participants from a united states college town using various methods: online ads, digital bulletins, social media posts, physical flyers, and online newsletters. To ensure diversity, we prioritized non-students by placing physical flyers in public spaces like restaurants, cafes, and libraries beyond campus. As we monitored respondent demographics, we began selectively accepting non-student participants. If a respondent self-identified as a student, we thanked them and informed them of our current priority for non-students, though some self-identified students were still accepted. To prevent response bias, we framed the study as focusing on attitudes toward societal issues rather than measuring cognitive load and behaviors. The college Institutional Review Board reviewed and approved this study.

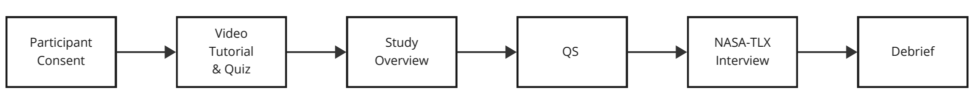


Fig. 9. Study protocol

Figure 9 visually represents the study protocol. Participants were invited to the lab to minimize external influences on cognitive load measurement and ensure consistency between sessions. The experiment involved participants using a 32-inch vertical monitor, ensuring all options on a QS were visible to minimize hidden information during decision-making. After consenting to the study, participants watched a pre-recorded video explaining the Quadratic mechanism and how QS operates without hints of interface operation. Participants then completed a short quiz to ensure their understanding of the QS mechanism. Those who failed to answer all questions correctly were asked to rewatch the video or consult the researcher until they could select the correct answers. The participant's screen was captured throughout the study. The researcher primed the participant that the study aimed to help local community organizers understand preferences on societal issues to better allocate resources. Participants were randomly assigned to one of four groups:

- 6 options with a text-based interface
- 6 options with an interactive interface
- 24 options with a text-based interface
- 24 options with an interactive interface

Participants completed the survey independently, without the researcher's presence. Upon completion, they contacted the researcher. The researcher distributed the NASA-TLX cognitive load measurement and a short semi-structured interview about their experiences. This interview

[2]link-to-github

was audio recorded. The session concluded with a debriefing and a $15 cash compensation. During the debriefing, participants were informed that the survey's true purpose was to measure cognitive load and interface design, and they could ask any questions.

4.2 Experiment Design Choices

This subsection details the justifications behind each experiment design decision. We made four major decisions:

4.2.1 A between subject study. We chose a between-subject study design for two main reasons. First, to minimize study fatigue given the complexity of responding to a QS survey, which could take up to 20 minutes. Conducting back-to-back experiments to measure cognitive load would be impractical, and asking participants to revisit the lab after several days would likely increase dropout rates and demotivate participants from attending in-person sessions. Second, we aimed to reduce the learning effect, which is challenging to eliminate, especially concerning interface operation and decision-making in the survey. Since preferences are constructed, we wanted to ensure that participants were not influenced by their previous preferences, which could affect their perceived cognitive load.

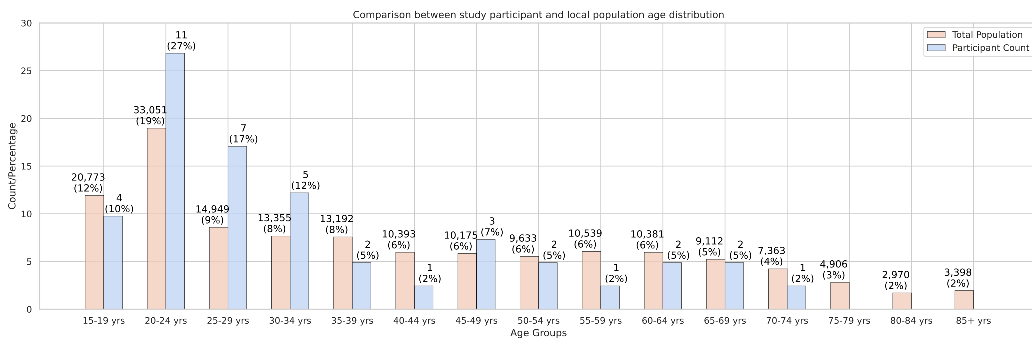
4.2.2 Deciding number of survey options. Ideally, understanding participants' cognitive load across multiple options would require enumerating all possible numbers of options to identify the "breaking point" where cognitive overload occurs. However, this approach is not feasible due to time and resource constraints. Therefore, we referred to prior literature to inform our choice of 6 and 24 options, representing short and long lists. Constant sum surveys and the Analytic Hierarchy Process (AHP) recommend fewer than ten and seven options, respectively [70, 71, 72]. Some refer to the value 7 based on human's cognitive processing capacity of 7 ± 2 [73] and a theoretical proof using the consistency ratio of a pairwise comparison metric [74]. A meta-analysis by Chernev et al. [75] surveyed 99 choice overload experiments and summarized that 6 and 24 are the modal values for short and long lists when testing choice overload. These two values were likely rooted in the original choice overload experiment[3] by Iyengar and Lepper [21]. Thus, we adopted these values to align with established research.

4.2.3 Context of the Study. Participants completed a societal issue survey, following the methodology described by Cheng et al. [2]. Surveying societal issues is relevant to every citizen, and easily conveys the concept of limited public sector resources that need prioritization across different areas. We curated a list of societal issues directly from the categories used by Charity Navigator [76], a non-profit organization that evaluates over 20 thousand charities in the United States. Participants across all four groups were presented with options randomly drawn from 26 societal issues. The full list of these societal issues is provided in Appendix **??**.

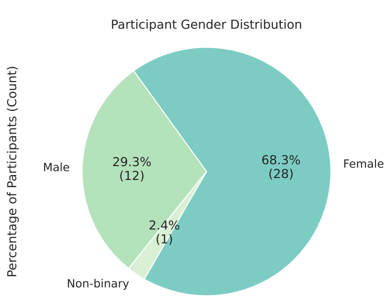
4.2.4 Using NASA-TLX to measure cognitive load. Several methods exist to measure cognitive load, including performance measures, psychophysiological measures, subjective measures, and analytical measures [77]. Given the nature of QS, a task requiring a long period, performance measures like secondary-task measures were challenging to implement due to the difficulty in designing a suitable secondary task. Psychophysiological measures such as pupil size [78] and ECG [79] are highly sensitive to external environments and costly to obtain. Consequently, we relied on subjective measures via self-report surveys and analytical measures like time and clicks collected via the interface. We adopted the paper-based weighted NASA Task Load Index (NASA TLX), a multidimensional scoring procedure using the weighted average of six subscale scores to

[3] We believe that the original value decision was due to the limitations of the jam flavors.

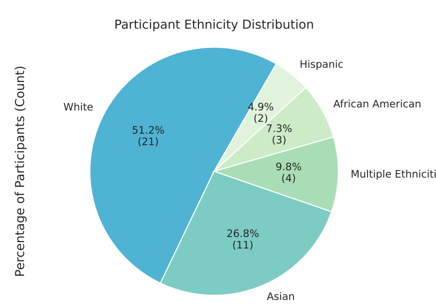
represent the overall workload. This process require subjects to evaluate each weight's contribution to the workload of a specific task [80, 81, 82] which reduced between-rater variability [82]. Despite criticisms regarding its validity and vulnerability, NASA-TLX is commonly used due to its low cost and ease of administration [77]. It has been tested on various experimental and lab tasks, showing significantly less variability among evaluators than one-dimensional workload scores [83]. Thus, we chose NASA-TLX to measure cognitive load in our study.



(a) Age distribution



(b) Gender distribution



(c) Ethnicity distribution

Fig. 10. Demographic distributions: Age, Gender, and Ethnicity

5 Cognitive Load and Sources across Experiment Conditions

In this section, we present the cognitive load across experiment groups and the sources contributing to each cognitive load dimension. Given the limited number of participants, we focus on descriptive statistics and qualitative assessments of cognitive load. Quantitative data includes metrics from the survey tasks, while qualitative insights come from post-survey interviews transcribed and analyzed by the first author.

To analyze the qualitative data, the first author conducted an inductive thematic analysis process [84]. They coded snippets from each transcript based on specific research questions and topics of interest for the qualitative analysis. Similar codes were merged within each research question or topic to form relevant themes. When differences were hypothesized, they applied a deductive coding process to text snippets related to a specific research question or topic of interest.

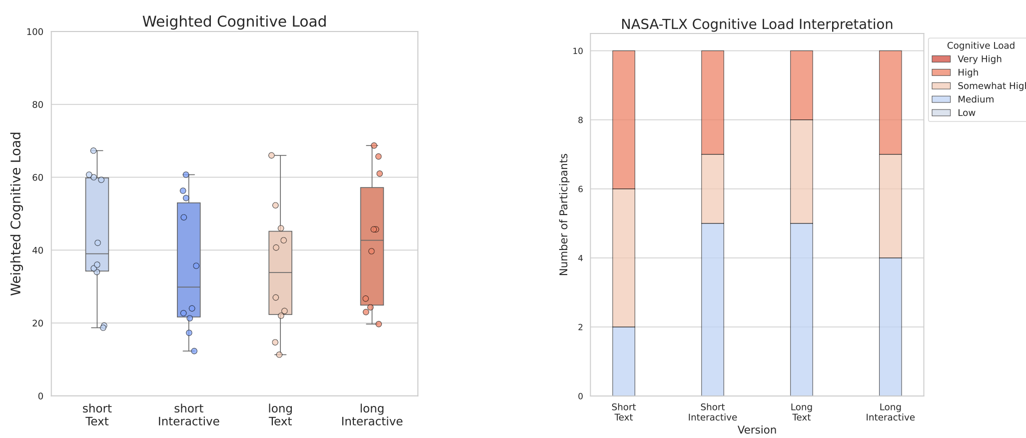
The results for this section are organized as follows: We start with participant demographics and then provide an overview of our cognitive load findings. We then examine the six dimensions used in the NASA-TLX survey: mental demand, physical demand, temporal demand, performance, effort, and frustration.

5.1 Demographics

We recruited a total of 41 participants, allocating ten to each experiment condition. Due to data quality concerns, we excluded one participant's data[4]. The mean age of the participants was 34.63 years old, with a detailed age distribution presented alongside the county population distribution in Figure 10a. This comparison reveals that our sample closely matches the county's demographic profile, albeit with a slightly higher representation of younger adults, particularly in the 35-45 age range. As shown in Figure 10b, the majority of participants skewed toward females.

Regarding ethnicity, 51.2% of the participants identified as White, 26.8% as Asian, 7.3% as African American, and 4.9% as Hispanic. Additionally, 9.8% of participants reported mixed ethnicity.

5.2 Overall Cognitive Load



(a) NASA-TLX Weight Score Distribution

(b) NASA-TLX Cognitive Interpretation

Fig. 11. This figure shows the box plot results for weighted NASA-TLX scores across experiment groups and participant counts based on individual score interpretations. In 11a, we observe a downward trend in cognitive load for the short QS, while the long QS shows an upward trend. Interestingly, there is a counterintuitive downward trend between short and long text interfaces. In 11b, these trends are clearer when NASA-TLX scores are grouped into five tiers.

To answer **RQ1** and **RQ2a**, we derive the weighted NASA-TLX scores across the four experiment conditions. We show these results in Figure 11. Weighted NASA-TLX uses a continuous 0-100 score, with higher values indicating greater cognitive load. We use predefined mappings of NASA-TLX values to cognitive levels: low, medium, somewhat high, high, and very high, as listed by Hart and Staveland [80]. We show value interpretations in Figure 11b. We find that:

[4]The participant stated they believed the experiment as a fake setup that they did not need to complete seriously.

- Short text interface: The median cognitive load was 39.00, with a mean of 43.23 and a standard deviation of 17.65. 8 participants reported somewhat high or above, with 4 reporting high cognitive load.
- Short interactive interface: The median cognitive load was 29.85, with a mean of 35.36 and a standard deviation of 18.17. 5 participants reported somewhat high or above, with 3 reporting high cognitive load.
- Long text interface: The median cognitive load was 33.85, with a mean of 34.60 and a standard deviation of 17.69. 5 participants reported somewhat high or above, with 2 reporting high cognitive load.
- Long interactive interface: The median cognitive load was 42.70, with a mean of 42.02 and a standard deviation of 18.48. 6 participants reported somewhat high or above, with 3 reporting high cognitive load.

These results partially answer our first two research questions. First, across the short survey, the interactive interface decreased cognitive load compared to the text interface. This is evident from the median cognitive load decrease from 39.00 to 29.85, with more participants reporting lower cognitive load using the interactive interface. The short text interface had the most participants ($N = 8$) rating their cognitive load as somewhat high or above. The other three conditions had similar distributions, with about half experiencing medium and half somewhat high or high loads.

Second, contrary to our expectations, the long text interface had a lower cognitive load than the long interactive interface. The cognitive load for the long text interface was even lower than that for the short text interface, with a median cognitive load of 33.85 compared to 39.00 in the short text interface. This is counterintuitive, as prior literature suggests that more options can heighten cognitive load [58].

By deduction, if the interactive interface increased cognitive load in the long survey, we might expect a similar increase in the short interactive interface compared to the short text interface. However, we observed a lower cognitive load in the short interactive interface. This discrepancy suggests two plausible explanations:

Interactive Interface prevents satisficing from cognitive overload. The long survey leads to cognitive overload and encouragesd satisficing behaviors, but the interactive components may have prevented participants from taking these mental shortcuts, which would typically reduce measured cognitive load [44, 45, 46, 47]. This prevention could result in a higher cognitive load in the long interactive interface compared to the long text interface. In other words, the interactive interface may have shifted participants' cognitive load from some dimensions to others, maintaining their overall cognitive load at a higher level but not overloaded. If this is true, we expect to see differences among the qualitative explanations of sources, specifically differences in the perceived causes of cognitive load. We will explore this in the next subsections (Subsections 5.3-5.8).

A Pure Increase of Cognitive Load Due to Interactivity. It is also possible that the long survey introduced statisficing behaviors due to cognitive overload, and the interactive interface did not influence participants' preference construction but only increased cognitive load due to the added interactivity. In other words, participants are asked to perform additional operations with interactive elements that contribute to a higher cognitive load without providing sufficient cognitive benefits. If this is true, we should expect behavior data to show similar voting patterns across conditions, as the added interactions primarily focused on the pre-organization of the options rather than influencing the decision-making process itself. We will explore this in the section 6.

We also acknowledge the possibility that the elicited values are pure noise and do not reflect the actual cognitive load. This could be due to the small sample size, the nature of the task, or the participants' understanding of the cognitive load scale. While this might be true for small sample sizes, we believe that the qualitative insights from the interviews provide a more nuanced understanding of the cognitive load sources. We detail these limitations in Section 8.

Table 1. This table lists all the causes participants mentioned as contributing to their Mental Demand. The shaded cells represent the percentage of participants citing each source of mental demand, allowing for comparison within columns. The abbreviations are: ST (Short Text Interface), SI (Short Interactive Interface), LT (Long Text Interface), and LI (Long Interactive Interface). Short and Long refer to the sum across both interfaces; Text and Inter refer to the sum across both survey lengths. We include Sparklines for comparisons across these experiment groups.

[Mental Demand]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Budget Management	14	3	3	5	3	6	8	8	6
Budget within limited credit	5	2	2	1	0	4	1	3	2
Track remaining credits	10	2	2	3	3	4	6	5	5
Maximize credit usage	8	2	3	2	1	5	3	4	4
Operational	12	3	2	4	3	5	7	7	5
Strategic	7	2	4	1	0	6	1	3	4
Preference Construction	39	10	9	10	10	19	20	20	19
Determining relative preference	16	4	4	5	3	8	8	9	7
Option prioritization	17	6	4	3	4	10	7	9	8
Precise resource allocation	30	9	6	9	6	15	15	18	12
Narrow - Consider a few options/personal causes	23	6	6	8	3	12	11	14	9
Broad - Considering all options or higher order values	23	5	5	4	9	10	13	9	14
Demand from Experiment Setup	24	6	6	6	6	12	12	12	12
Many options on the survey	6	0	0	3	3	0	6	3	3
QS Mechanism	4	2	0	2	0	2	2	4	0
Recalling experience or understanding options	20	5	6	4	5	11	9	9	11
Justification or Reflection on response	8	2	2	1	3	4	4	3	5
External Factors	12	3	1	4	4	4	8	7	5
Demand due to Interface	8	2	2	0	4	4	4	2	6
Increase	4	1	1	0	2	2	2	1	3
Decrease	4	1	1	0	2	2	2	1	3

5.3 Source of Mental Demand

> ℹ **Summary:** Participants across all groups highlighted **budget management** and **preference construction** as their primary sources of mental demand. We observed two key differences: First, slightly more participants using the text interface reported mental demand from precisely determining the number of votes for options compared to the interactive interface. Second, when it comes to long QS, participants using the long interactive interface considered broader societal impacts and evaluated options holistically, while those in the long text interface focused on personal relevance and individual issues. These differences indicate that the interactive interface encouraged deeper thinking, shifting the source of mental demand.

Mental demand refers to the extent of mental and perceptual activity required. Interview results showed the top two causes that increased participants' mental demand were *Budget management* and *Preference construction*. Table 1 listed all causes. We discuss in detail below.

Fourteen participants expressed demand from budgeting within limited credit (N=4), tracking remaining credits (N=10), and maximizing credit use (N=8). For example:

5.3.1 Mental Demand Source: Budget management. 14 participants expressed demand from budgeting within limited credit ($N = 4$), tracking remaining credits ($N = 10$), and maximizing credit use ($N = 8$). For example:

> *How many I got left that ... that I haven't voted on yet, and seeing if I and looking at the remaining credits, I'm trying to mentally divide that up before I start allocating upvotes and downvotes.*
>
> *– S006, long interactive interface, budget within limited credit*

> *And then I just wanted to make sure that I used all the credit that I had available to me, and also knowing that in order to like show your support for certain societal issues you had to like that was giving a tangential take away from other societal issues that you could support as well.*
>
> *– S032, short text interface, track remaining credits.*

In the first quote, the participant struggles with not running out of credit while allocating credits. The second quote highlights the challenge of maximizing spend while ensuring sufficient differentiation. Both relate to effective budget management.

We further categorized budget management causes as operational (completing an operation, e.g., using the last credit) or strategic (achieving a higher goal, e.g., spreading credits across options). Strategic planning does not refer to gaming out others or 'winning' a game but rather to high-level thinking processes that consider strategies and plans to tackle a challenge, compared to operational tasks such as adjusting a specific vote value. Most long survey participants reported operational causes, indicating they didn't face enough mental demand to consider additional strategies.

5.3.2 Mental Demand Source: Preference construction. Almost all participants ($N = 39$) reported increased mental demand from preference construction. We broken it down into three sources: determining relative preference ($N = 16$), option prioritization ($N = 17$), and precise resource allocation ($N = 30$), For example, participants would focus on internal evaluation and construct comparisons among different options:

> *Figuring out my priorities, and how much I prioritize option 1 over option 2. What is the difference between those 2 on my priority list?*
>
> *– S002, short interactive interface, determining relative preference*

Participants would locate higher priority options through trade-off decision making or map existing internal preferences into a subset of options:

> *I knew which ones that I wanted to dedicate the most to, and I knew which one I wanted to dedicate the least to. But it was that middle area that was kind of a grey area.*

– *S008, short interactive interface, option prioritization*

Finally, participants tried to allocate specific values or make specific adjustments to represent their preferences.

> *I'm not sure how to put into words … like having to pick how many upvotes would go to each one*
> – *S023, long text interface, precice resource allocation*

Almost all participants mentioned preference construction as a source of mental demand, supporting the theory that preference construction is a difficult and mentally demanding task. Notably, more participants using the text interface reported mental demand from precise resource allocation compared to the interactive interface (18 vs. 12). We conjecture that the interactive interface helped participants make more informed decisions, reducing their mental demands in this area.

5.3.3 Mental Demand Source: Other Sources. We identified four additional sources causing participants' mental demands: *experiment setup*, *number of options*, *QS mechanism*, and *external factors*.

24 participants mentioned the experiment setup mainly related to understanding and recalling their experience with the options. 6 participants, all from the long QS, found the number of options added mental demand. 4 participants cited working with getting familiar with the QS mechanism as a source of mental demand. These are sources related to the study design. 12 participants mentioned external factors, such as considering the consequences of their results or the challenges decision-makers face. 4 participants reported an increase and another four a reduction in mental demand due to the interface design. 8 participants expressed mental demand from justifying their choices and reflecting on their responses, questioning whether their votes truly reflected their preferences or if the amount of credit spent was justified.

5.3.4 Takeaway: A different scope of preference construction and budget management approach among long QS groups. While these sources are common across all experiment groups, we highlight a notable difference when we focus on participants across interfaces completing the long QS. **They focus on a different scope of preference construction**. More specifically, participants ($N = 8$) in the long text interface tend to experience mental demand from preference construction by thinking about issues more narrowly and focusing on personal relevance. Conversely, participants ($N = 9$) in the long interactive interface experience higher mental demand from considering the broader societal impact and evaluating options more comprehensively. Only four participants in the long text interface expressed a comprehensive view, and three participants in the long interactive interface expressed a narrow and personal view.

> *Trying to figure out what upvotes I should give it you know … compared to … I even kind of went back compared to the other topics: <topic one> compared to <topic two>, and even with like <topic three>, I kind of went back and forth between those two. […] So it was very mental tasking for me.*
> – *S015, long text interface*

> *[…] really going through the rest of the categories and deciding okay, which are the pressing issues of our time and which are the pressing issues for this particular society that that I live in. […] You know these causes need a lot more funding, and and others can probably still have some sort of an impact, even with less resources.*
> – *S019, long interactive interface*

In the first quote, participants felt mental demand focusing on three options, trying to recall specific characteristics to differentiate them. In the second quote, participants considered the societal impact of options, aiming to maximize their effect. This difference highlighted our belief that the organization phase prompted participants to consider a broader range of factors in their decisions. Across both interfaces, participants in the long survey tended towards operational mental demands related to budget management. We argue the interactive interface prevented participants from using heuristics to narrow their choices, which only appeared when final votes were determined, an area with less support from the interface. We conclude the interactive interface scaffolded the decision-making process, preventing satisficing behaviors because of cognitive overload, and thus shifted mental demand sources. This shift explains why we did not notice significant differences in mental demand raw values (Figure 12) across the four experiment groups.

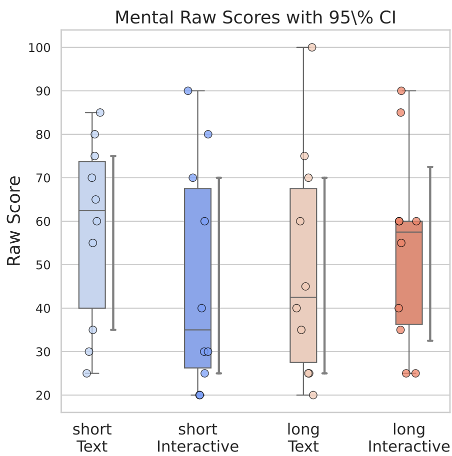


Fig. 12. Mental Demand Raw Score: Across all four experiment groups, participants' reported mental demand is spread across a wide range with many participants experiencing high mental demand.

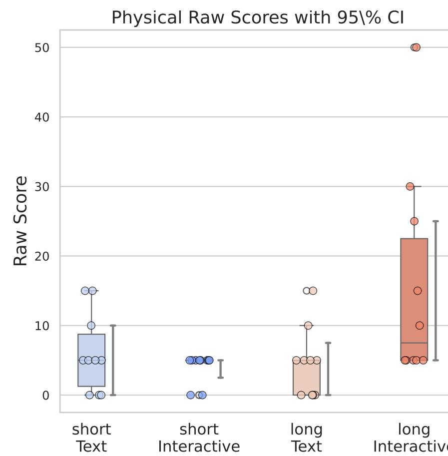


Fig. 13. Physical Demand Raw Score: Participants other than the long interactive interface reported minimal physical demand. The long interactive interface had the highest physical demand, likely due to increased mouse clicks and extended time spent looking at the vertical screen.

Table 2. Physical Demand Causes: Most participants expressed little or no physical demand. Results reflected that participants in the long interactive interface required more actions, hence the higher mention of mouse usage as a source.

[Physical]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Reading	4	0	2	1	1	2	2	1	3
Mouse	16	3	5	2	6	8	8	5	11
Vertical Screen	4	1	0	1	2	1	3	2	2
None/Little	32	8	9	8	7	17	15	16	16

5.4 Source of Physical Demand

Summary: Participants across all groups highlighted *reading*, *using the mouse*, and *navigating a vertical screen* as cause of physical demand. Most participants experienced little or minimal physical demand. Interactive interface users experienced higher physical demand due to increased mouse usage.

Physical demand refers to the physical effort required to complete a task, such as physical exertion or movement. Since this study involves participants sitting in front of a computer screen completing a survey, most participants reported minimal physical demand($N = 32$). We nonetheless report the sources of this minimal demand, which include reading text on the screen ($N = 4$), using the mouse ($N = 16$), and moving their head to navigate the vertical screen ($N = 5$). Participants emphasized that these demands were minimal, which is reflected in the low values reported in the NASA-TLX physical demand scores (Figure 13)

Notably, 11 out of 20 participants who used the interactive interface mentioned physical demand from using the mouse, reflecting their increased interaction with the interface. Table 5 shows the distribution of participants across different sources of physical demand. This is further supported by the raw NASA-TLX physical demand scores, which show a significant visual difference between short and long interactive interfaces as well as between text and interactive interfaces in long surveys.

Table 3. Temporal Demand Sources: Decision-making and Operational Tasks are the main causes. Participants framed their decision-making sources differently.

[Temporal]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Budget Management	4	0	1	1	2	1	3	1	3
Decision Making	15	5	2	3	5	7	8	8	7
Affirmative	9	0	2	2	5	2	7	2	7
Negative	8	5	1	2	0	6	2	7	1
Operational	16	5	6	3	2	11	5	8	8
Task completion	8	2	2	3	1	4	4	5	3
Being efficient	8	3	4	0	1	7	1	3	5

5.5 Source of Temporal Demand

Summary: Participants faced increased temporal demand from: *Budget*, *Decision Complexity*, and *Operational Tasks*. Notably, the interactive interface managed temporal demand more effectively, allowing participants to pace themselves and avoid misperceiving task difficulty.

Temporal demand measures the time pressure participants feel during a task. Lower demand means a more leisurely pace. The main sources of increased temporal demand are (Table 3) of increased temporal demand are: *Budget*, *Decision Complexity*, and *Operational Tasks*.

5.5.1 Temporal Demand Source: Budget. Budget emerged as a theme across all conditions, with four participants feeling rushed as their credits decreased, translating the increasing marginal cost of votes into higher temporal demand. As one participant said:

> *When the money was decreasing, as I was casting more upvotes or downvotes so as the money decreases I felt kind of rushed.*
>
> *– S034, long interactive interface*

5.5.2 Temporal Demand Source: Decision Complexity through different lens. Decision Complexity refers to when participants felt that there are many decisions to make. These causes appear in two forms – affirmative and negative. Affirmative perception refers to participants explicitly expressing that there are many decisions *to make*, while negative perception refers to participants describing concerns regarding the time and effort *already invested* in the survey.

> *[...] when you are being presented the ideas that they're that they are being put together, and you need to allocate the resources ... Say, you know, this one is more important than that one ... that's the part when it gets tricky, so that you spend more time here.*
> – *S037, long interactive interface*

> *[...] so at first it was like, 'Okay, this is fine.' But then on the end, I was like, maybe I should just hurry up and make a decision. So it's like at first it would been here, but then I kinda moved up near the end when I was hanging a waffling between my upvotes.* – *S024, short text interface*

The first quote illustrates temporal demand from the decisions participants need to make. The second highlights demand from the time already devoted. In the short text interface, half of the participants expressed negative perceptions of temporal demand, whereas in the long interactive interface, half had affirmative perceptions.

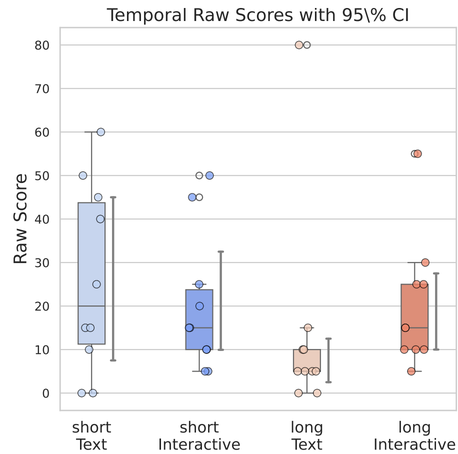


Fig. 14. Temporal Demand Raw Score: The short text interface results in the highest temporal demand, while the long text interface has the lowest. Both interactive interfaces, particularly the short interactive, show moderate temporal demand, suggesting that interactive elements help manage time pressure more effectively, allowing participants to pace themselves better and engage more deeply in the tasks.

5.5.3 Temporal Demand Source: Operational Tasks. Operational tasks involve actions like updating votes and completing the survey. For instance, one participant aimed to operate swiftly:

> *I wanna get through things in an efficient manner which doesn't necessarily mean I rush it. But it does mean that I do things expeditiously. Especially. I'd like to think I'm somewhat computer-savvy. And so to be able to move through this quickly and efficiently. I do take pride in, but it's all personal stuff. It's not nothing outwardly influencing me.*
> – *S032, short text interface*

> *I want the credit done but I don't want to be overthinking.*
> – *S013, short text interface*

The first quote refers to the participant's aim to operate swiftly on the interface, not specifically related to decision making. Similarly, the latter focuses on using the credit to complete a specific goal. We found that temporal demand is higher for the short survey experiment group. Over half of the participants from the short interface wanted to complete the task swiftly and quickly, compared to 5 participants from the long QS group.

5.5.4 Takeaway: Temporal demand managed through interactive interface. The raw NASA-TLX values in Fig 14 visually indicate two important points. First, temporal demand trended lower for the interactive interface in the short QS condition, while it trended higher for the long QS condition. Second, the long text interface exhibited the lowest temporal demand, which is counterintuitive since participants in this condition made no fewer decisions and operations compared to the short text group. According to our interpretation of mental demand results in Section 5.3.4, participants likely did not experience temporal demand because they applied heuristics to reduce the number of decisions, thereby lowering their cognitive load and decision-making instances.

Additionally, participants in the long interactive condition reported that the numerous required operations created temporal demand, preventing them from taking mental shortcuts and shifting their cognitive load to different dimensions.

Furthermore, participants in the short text QS expressed high temporal demand and perceived it negatively, likely misperceiving task difficulty. Conversely, even though the short interactive interface required more decisions, participants reported less temporal demand from decision-making, resulting in a lower overall score. This suggests that the interactive interface slowed them down without increasing temporal demand, allowing them to pace themselves and engage in more in-depth thinking, thereby preventing a misperception of task difficulty.

These observations across experimental conditions support the plausible explanation that the interactive interface mitigated satisficing behaviors due to cognitive overload, as evidenced by the different sources of temporal demand.

Table 4. Performance Causes: Most causes are shared across experiment conditions. We provided qualitative interpretations of their own perfornace assessments.

[Performance]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Operational Action	13	2	3	3	5	5	8	5	8
Budget Control	6	1	1	2	2	2	4	3	3
Preference Reflection	6	1	1	2	2	2	4	3	3
Limited Resources	5	1	2	1	1	3	2	2	3
Social Responsibility	8	2	2	2	2	4	4	4	4
Decision maker	7	1	2	2	2	3	4	3	4
Outcome Uncertainty	7	1	2	2	2	3	4	3	4
Performance Assessment									
Did their best	8	2	1	3	2	3	5	5	3
Feel Good	17	3	5	3	6	8	9	6	11
Good Enough	10	2	2	3	3	4	6	5	5

5.6 Source of Performance

Summary: Participants experienced performance demands due to *Operational Actions* and *Social Responsibility*. Despite similar performance scores across groups, more participants using the interactive interface felt more positive about their performance.

Performance refers to a person's perception of their success in completing a task. Lower values mean good performance; higher values mean poor performance. We found minimal qualitative differences between experiment groups regarding influence sources. We identified two performance demands from the interviews: *Operational Actions* and *Social Responsibility*. Despite most participants reporting positively on their performance, nuances exist in how different groups interpret their performance.

5.6.1 Performance Source: Operational Actions. Operational actions, like the theme presented in temporal demand, refer to specific, executable procedures participants perform in the survey. All experiment groups share these sources. Six participants felt pressured to spend all their credits or stay within budget. Five participants worried choice of votes didn't reflect their true preferences. Additionally, six participants experienced performance demand due to limited time, energy, and resources, which ties into other specific cognitive demands like decision fatigue and time pressure. Here we show two examples:

> *I don't think I did it perfectly, because I didn't have 0 remaining credits.*
> *– S024, short text interface, budget management*

> *I'm concerned that it's not as reflective of my views as I wanted to be like, or I was concerned about it. [...] I was concerned that maybe it didn't.*
> *– S041, long text interface, preference reflectiveness*

5.6.2 Performance Source: Social Responsibility. Social Responsibility is a noteworthy performance demand, categorized into *decision-maker responsibility* (N=8) and *uncertainty of the outcome* (N=3). The former refers to individuals feeling guilty because they couldn't avoid specific tradeoffs or wanted to be fair. This theme resembles 'External Demand' in Mental Demand. For example,

> *I don't want people to think that I just like don't care about <ethnicity> people at all. I also don't think like government funding should go towards like religious organizations. You know what I mean. So I don't want somebody to think that like, I just don't care about <ethnicity> people.*
> *– S041, long text interface, decision-maker responsibility*

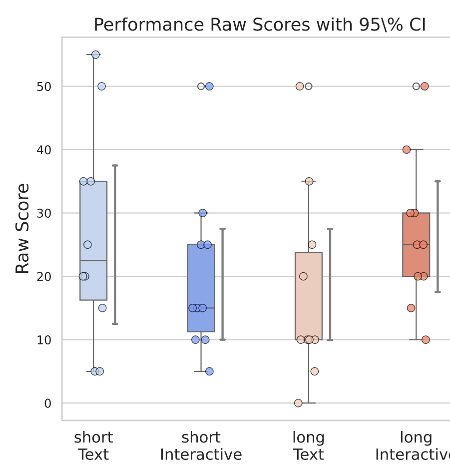


Fig. 15. Performance Demand Raw Score: Participants showed indifferent performance raw scores across experiment conditions, all trending toward satisfactory.

In this quote, the participant put themselves inside the shoes of a member of the government, rather than a citizen expressing their own attitudes. This shift in roles introduced the performance demand and demonstrated that QS mirrors the decision-maker's dilemma in individual survey responses. This characteristic also applies to the latter, further highlighting participants' attempts to foresee an outcome:

> *If I was actually running a government funding [...] I don't know how this (the survey results) might actually affect people. Some of these things might be unpopular or bad, or have outcomes that I didn't forsee.*
> *– S027, short interactive interface, uncertainity of the outcome*

Social responsibility also spans experiment groups. Raw NASA-TLX scores (Figure 15) show participants had indistinguishable performance scores. This aligns with the interview results where most participants felt positive about their final submission. We also analyzed participants' satisfactory statements regarding performance.

5.6.3 Takeaway: Half of the participants using the interactive interface Felt good. We identified three types of satisfactory statements regarding self-reported performance:

- *Did their best* refers to statements where a participant stated they exhausted their maximum effort to complete the task.
- *Feel good* refers to statements where a participant expressed positive emotions or satisfaction about their performance or the outcome.
- *Good enough* refers to statements where a participant acknowledged that their performance or the outcome was acceptable or satisfactory, but not necessarily perfect or the best possible.

Approximately the same number of participants in each of the four experiment groups expressed *Good enough*. Meanwhile, participants using the interactive interface across short and long groups had almost double the number of participants ($N = 11$) who expressed *Feel good* compared to the text interface ($N = 6$).The text interface had slightly more participants ($N = 5$) who expressed *Did their best* compared to the interactive interface ($N = 3$).

These results highlight key takeaways: First, participants from all experiment groups expressed satisficing behaviors (*Good enough*) at similar frequencies. Second, participants using the interactive interface were generally more positive about their experience and the outcomes.

Table 5. Mental Demand Sources: Participants using the text interface focused more on operational tasks, while those using the interactive interface focused more on strategic planning.

[Effort]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Operational	21	6	5	8	2	11	10	14	7
Strategic	28	6	8	5	9	14	14	11	17
Personal	22	4	7	5	6	11	11	9	13
Global	11	2	3	2	4	5	6	4	7
None/Little/a bit	9	2	1	3	3	3	6	5	4

5.7 Source of Effort

> **Summary:** Effort sources varied between operational *Operational Tasks* and *Strategic Planning*. Participants using the text interface focused on operational tasks, while those using the interactive interface engaged in strategic planning. This shows that the interactive interface spurs deeper, more critical thinking.

Effort refers to work required to achieve a level of performance. It includes the intensity of both mental and physical resources expended during the task. We identified two major sources of effort: *Operational Tasks* and *Strategic Planning*.

5.7.1 Effort Source: Operational Tasks. Operational Tasks that increase effort includes navigating the interface, managing the budget at an operational scale (i.e., making sure not to run out of budget, making specific updates between two options), or translating opinions into quantifiable adjustment on the survey, all directly related to manipulating the interface. We show two examples:

> *And then I wanted to bump up (an option) maybe to 4 or <option> to 5 and realize I couldn't. My point (number of votes) had to like back down a little bit . . . So that would be effort came in of how do I want to really rearrange this to make it (the budget spending) maximize?*
>
> *– S029, short text interface*

So it was like it was very . . . I have to put a lot of effort in terms of you know . . . think about each dimension that if I give one credit to <option name> whether it will affect my credits on <another option name>.
– *S005, long text interface*

Both quotes illustrated participants putting in effort to manipulate the interface. 14 of the 20 participants using the text interface mentioned these effort sources, compared to 7 using the interactive interface, with the lowest mention by the long interactive interface group ($N = 2$).

5.7.2 Effort Source: Strategic Planning. Strategic planning is similar to strategic budget management mentioned under mental demand. Unlike operational tasks, strategic planning involves higher-level strategies to complete the survey. We categorize two distinct types of planning: *personal* and *global*. *Personal strategic planning* involves translating preferences onto the survey without considering broader values or beliefs. For example:

[. . .] having that prior experience and being able to quickly link it to a tangible thing that I've experienced in my personal life.
– *S032, short text interface*

And really the bulk of the effort was how to rank order these (options) and allocate the resources behind the upvotes so that I can accurately depict what I want . . . say, a committee to focus on and allocate actual fungible resources, too.
– *S019, long interactive interface*

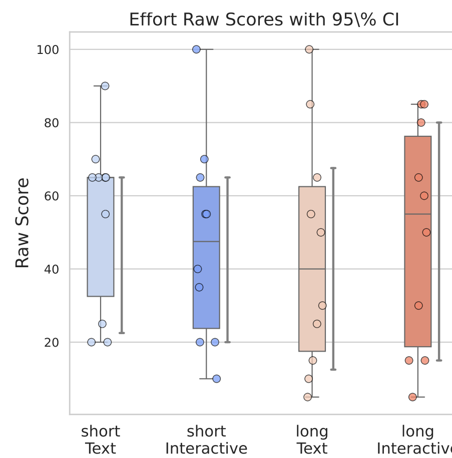


Fig. 16. Effort Raw Score: Effort scores shows indifference across groups.

Participants using the interactive interface ($N = 13$) mentioned personal strategic planning slightly more than those using the text interface ($N = 9$). *Global strategic planning*, on the other hand, involves formulating strategies to align with broader communal values, such as fairness and community impact. For example:

I think, imagining the trying to imagine every outcome trying to to imagine what what else would be encompassed, encompassed by each category.
– *S027, short interactive interface*

Hey, even though I don't really like this idea. But what if they're important? They sort of kind of deserve some attention . . . that's why I think I have the effort here.
– *S037, long interactive interface*

Both examples show considerations beyond personal experiences, including outcomes or social values. Nearly twice as many participants using the interactive interface ($N = 7$) mentioned global strategic efforts compared to the text interface ($N = 4$). Overall, more participants using the interactive interface ($N = 17$) reported sources of strategic effort compared to those using text-based interfaces ($N = 11$).

5.7.3 Takeaway: Interactive interface spurs more strategic effort from participants. Effort is a realization of mental demand through physical actions. Since participants experienced little physical demand, the sources of effort reflected how individuals translated their mental demand into efforts. The raw NASA-TLX effort scores (Figure 16) showed a similar spread across experiment groups, akin to mental demand. However, qualitative analysis revealed that participants using the text interface experienced more effort focused on operational tasks (i.e., completing specific tasks). In contrast, participants using the interactive interface experienced more effort focused on strategic planning (planning a strategy to complete tasks). Specifically, those using the interactive interface engaged in global strategic planning, considering options comprehensively and beyond the immediate task. This contrasts with text interface participants, who concentrated more on operational tasks and narrower strategic planning. This finding reinforces that cognitive load sources differ between interfaces, with interactive interfaces fostering deeper, more critical thinking.

Table 6. Frustration Sources: needs to be updated with some new terms definitions for some of the columns.

[Fustration]	Total	Version				Experiment Conditions			
		ST	SI	LT	LI	Short	Long	Text	Inter
Strategic	17	4	4	5	4	8	9	9	8
Higher-level	11	3	2	3	3	5	6	6	5
x Conflict between personal preference and broader society and common values	6	1	1	2	2	2	4	3	3
x Trade-offs among all options	8	3	1	2	2	4	4	5	3
Lower-Level	10	3	3	2	2	6	4	5	5
x Conflict between personal preference and	4	1	2	0	1	3	1	1	3
x Trade-offs among a few options	8	2	2	2	2	4	4	4	4
Operational	15	4	5	2	4	9	6	6	9
Credit management	6	2	3	1	0	5	1	3	3
Adhering to the Quadratic Mechanism	5	2	1	1	1	3	2	3	2
Deciding number of votes for an option	4	2	0	0	2	2	2	2	2
Making multiple decisions	3	2	0	0	1	2	1	2	1
Understanding Option	4	0	3	0	1	3	1	0	4
None/Little	16	4	5	5	2	9	7	9	7

5.8 Source of Frustration

> **Summary:** Participants experienced frustration from two main sources: *Operational Actions* and *Strategic Planning*. We observed evidence that participants in the long text interface showed little frustration, specifically from operational sources, indicating satisficing behaviors.

Frustration refers to the extent to which the participant is annoyed, irritated, or discouraged during the task. Sources of frustration are grouped into two major themes: *Operational Actions* and *Strategic Planning*.

5.8.1 Operational Actions. 15 participants highlighted this source for frustration. 6 participants expressed frustration regarding credit management (i.e., overspending budget); 4 participants mentioned had trouble deciding the final value for the options; 3 participants are frustrated because they need to make multiple decisions; 5 participants were frustrated with the quadratic mechanism; 4 participants are frustrated trying to understand the content of the option or how the option connects to them. For example,

> *I was slightly frustrated when doing the task, probably because there was a budget that we kind of had to stick with it.*
>
> *– S001, long text interface, quadratic mechanism*

i think just frustration [...] because when i was making like the decisions on how many upvotes I could put in each section, I was running out of credits.

– S013, short interactive interface, budget management

These demonstrate participants' frustration when hindered by operational actions or constraints presented by QS. Notably, almost half of the participants in all experiment groups expressed operational frustration, compared to only two participants from the long text interface group.

5.8.2 *Strategic Planning.* We derived strategic planning into two types: *lower-level* and *higher-level*. Four participants experienced conflict between their own and others' preferences. Eight participants experienced conflict when making trade-offs among a few options. For example:

Because I know that's important to other people. But it just doesn't to me.

– S010, short interactive interface

I would have loved to have given more to other groups . . . and I felt stressed like [. . .] well . . . it's a group that you know is still . . . you know . . . important [. . .] – S020, long text interface

These quotes show participants adhering to lower-level strategies like balancing personal preferences and smaller trade-offs. Compared to *higher-level strategic planning*, 6 participants expressed conflicts involving broader societal concerns and core values. 8 participants felt frustrated by being forced to make trade-offs among *all* options. For example,

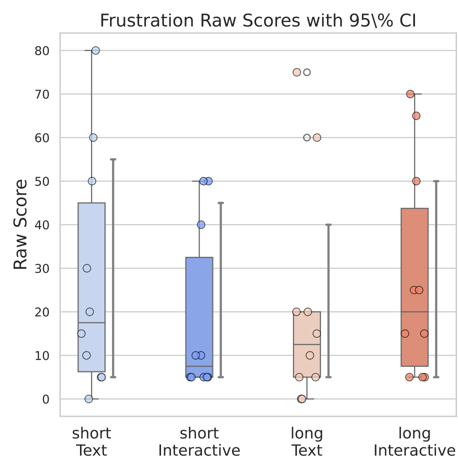


Fig. 17. Fustration Raw Score: Participants other than the long text interface highlighted seversl operational tasks that led to fustration. All groups share causes from strategic planning.

I had to consider how I feel towards that . . . how religious media broadcasting is being used in like today's society . . . today's political environment. So yeah . . . you really have to consider what is important to you. – S020, long text interface, value conflicts

I think the frustration is . . . I wish that we could help all of these causes, but you know it's just like anything else. You can't do everything and when it's not . . . I feel like it's hard to quantify how much some of these things should be supported versus others. So when you're talking about upvotes and things that's challenging to me, it's frustrating. *– S026, long interactive interface, considering all options*

All experimental conditions noted similar frustration related to strategy planning, across lower-level and higher-level frustration.

5.8.3 *Takeaway: Long text interface exhibits choice overload evidence.* Across all experimental conditions, participants experience similar sources related to strategic planning. The long text interface condition had the fewest participants expressing operational frustration, with half expressing no frustration. Similar trends appear in the raw NASA-TLX scores (Figure ??), where participants in the long text interface exhibit a much lower frustration score. Both qualitative interview and NASA-TLX scores align with prior literature [85, 86], indicating that satisficers tend to be less frustrated and happier than maximizers. This suggests that participants in the long text interface exhibit satisficing behaviors, further supporting our claim that the interactive interface can reduce satisficing behaviors in QS tasks.

5.9 Summary: Interactive interface prevents satisficing, especially for long QS

We find evidence across all six dimensions contributing to cognitive load that supports the claim that the **interactive interface prevents satisficing due to cognitive overload**. Evidence from mental demand shows that in the long interactive interface, participants focused more on deeper thinking and were less burdened by precisely determining the number of votes for a few options. Participants using the interactive interface paced themselves better and felt more positive about their performance. Participants devoted more effort, leading to deeper and more critical thinking when using the interactive interface. Participants using the long text interface engaged in satisficing. Despite not seeing drastic differences in the weighted NASA-TLX results and being unable to show strong evidence that the interactive interface is necessary for short QS, our qualitative analysis reveals why long QS need an interactive interface.

In the next section, we further triangulate our hypothesis by examining participant behavior data to show how participants in the long interactive interface behave differently than those in the short interactive interface.

6 Behavior Results

To answer RQ3, we investigate time-to-action and remaining credit differences across experiment conditions. Time-to-action is a widely used metric in decision sciences to understand individual behaviors. For example, Payne et al. [87] theorized that longer decision time represents more complex and deeper cognitive processing. Additionally, resource allocation strongly influences decision making. Cheng et al. [2] showed that the number of given credits influences the validity of QV. Decision science studies like Shah et al. [88] and [89] showed how scarcity influences decisions, increases risk aversion, and adds cognitive load. In this section, we use these two measures as proxies to understand participant behaviors. We publicly shared all analyzed participant interaction data[5] to support transparency and facilitate further research.

6.1 Time Spent per Options

Our first analysis focuses on understanding how much time participants spent per option across different stages and experiment conditions. Based on the QS system log, we can derive the following detailed logs of participant actions: *the option* involved in the interaction, *the type of interaction* (such as updating a certain number of votes), and *the time* between this interaction and the previous one.

We aggregate all the time spent on each option as the total time spent for that option. Organization time includes the time participants spent placing options into preference categories and the drag-and-drop time associated with each option during the organization phase. Voting time strictly refers to the time participants took to update vote values for each option. To minimize noise, we intentionally drop all the time participants spent on the first option in the organization phase or voting phase. The goal is to exclude time spent on reading the prompt, forming their preference, or understanding the interface.

Figure **??** each dot represents one option for one participant. Figure 18a shows total time, figure 18b shows organization time, and figure 18c shows voting time. The violin plot shows the distribution of the dots and the three horizontal lines represent the median, 25th percentile, and 75th percentile of the time spent for that interface. We limited the y-axis to 1 minute to improve visualization clarity.

Participants spent more time on the interactive interface than the text interface in both short and long surveys. A non-parametric Mann-Whitney U test confirmed this observation. For the long QS,

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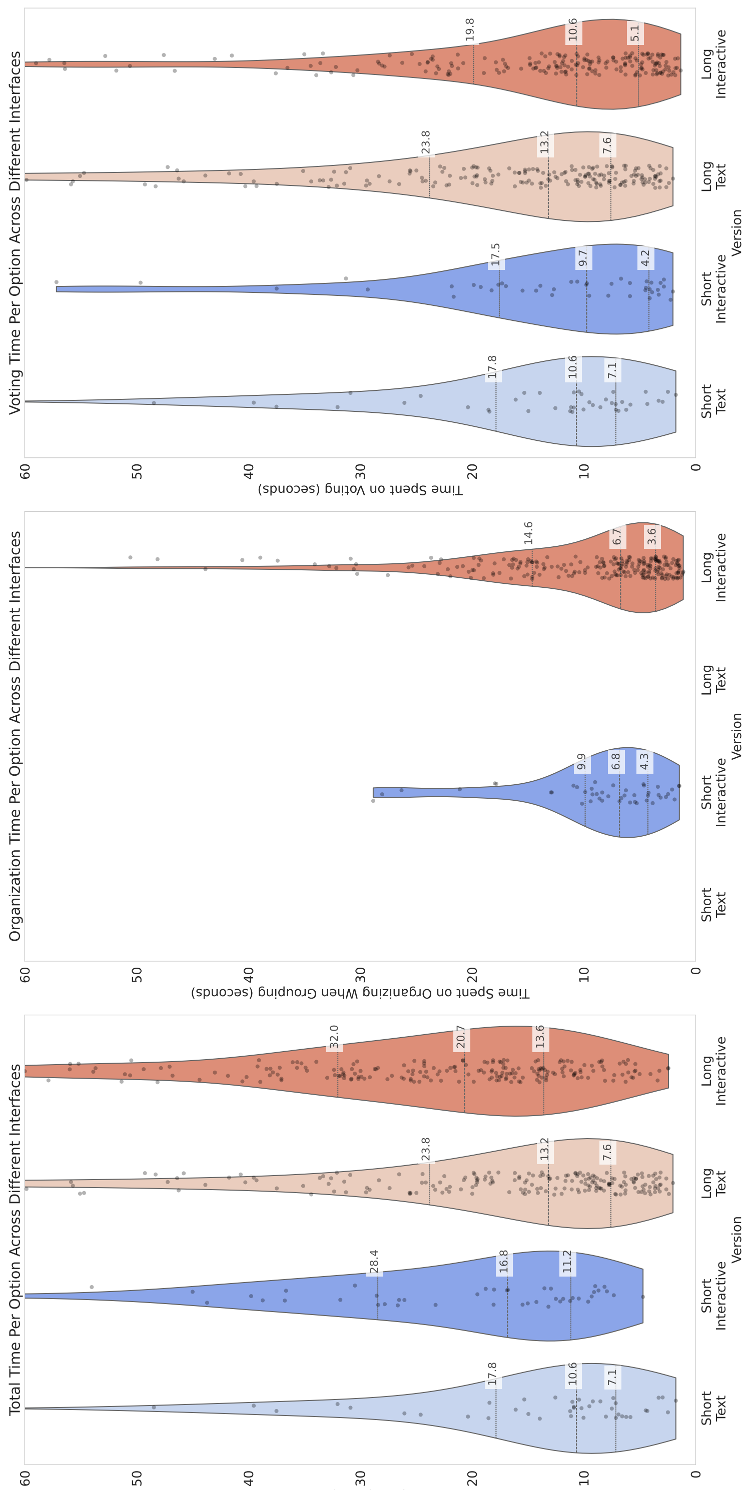

(a) Total Time per option

(b) Organization Time per option

(c) Voting Time per option

Fig. 18. Swimlane Diagram

the Mann-Whitney U test results showed a significant difference between the text interface and the interactive interface ($U = 15536$, $p < 0.0000001$). The effect size was small (Rank-biserial: -0.304, Cohen's d: -0.030) and the power of the test was 0.061. For the short QS, the Mann-Whitney U test results showed a significant difference between the text interface and the interactive interface ($U = 573$, $p = 0.01$). The effect size was small (Rank-biserial: -0.37, Cohen's d: -0.082) and the power of the test was 0.066. These results indicate that participants spent slightly less time on the text interface. This is expected as organizing options in the interactive interface takes more time. We break down the total time spent into organization time and voting time in Figure 18b and Figure 18c.

We observed minimal difference in organization time (Figure 18b) between short and long interface. The interface was designed with this in mind given that options are shown one at a time, and participants can drag and drop them into the preference categories when needed. Examining the voting time (Figure 18c), there is no significant difference in voting time between the text and interactive interfaces in the short survey ($p > 0.4$, Power=0.051). However, in the long QS, there is a statistically significant difference ($U = 24053$, $p < 0.005$) in voting time between the text and interactive interfaces. The effect size was small (Rank-biserial: 0.167, Cohen's d: 0.017) and the power of the test was 0.053. This indicates that participants spent slightly less time on the interactive interface in the long survey. This supports our hypothesis that the two-step design in the interactive interface facilitates more efficient decision-making, especially in longer surveys.

6.2 Budget and Voting Behaviors

To further analyze participant behaviors, we break down the aggregated time from the previous analysis and examine fine-grain interactions. Specifically, we examine if there are differences among behavior across interfaces. As we outlined, credit scarcity might influence decision making. Figure 19 plots the time of voting actions over the remainder of the participant's budget across the text and interactive interface across all four groups. Each bar shows the number of actions accumulated across participants at specific percentages of remaining credits. A KDE plot is provided to better visualize the trends. We chose not to follow Quarfoot et al. [25] focusing on the number of accumulated votes over an individual's time given that each individual's total time spent differ across experiment conditions.

Comparing experiment groups, we see fewer differences in the short QS but different interaction distributions between the two interfaces in the long QS. Given the significant differences in voting time between the text and interactive interfaces for the long QS, we focus on deciphering the voting action changes between these two conditions in this subsection.

In Figure 19, we see two distinct patterns between the short survey and the long survey in terms of participant behaviors. In long surveys, participants exhibited more actions both when the budget was abundant and when it began to run out. This pattern was more pronounced with the long interactive interface. We further separated the behaviors where participants made large or small changes to the options, specifically for the long version. In Figure 20, we define an adjustment of four or more votes as large, which we plotted in the first row of the figure. Adjustments of two or fewer votes are considered small, which is 10% of the possible values one can choose among the maximum of 21 votes.

Instead of showing the number of actions, we plotted all actions against the time it took to make them. Revisiting the KDE curve in the second row in Figure 19 and the curve of the second row in Figure 20 which represents the small vote adjustment across both interfaces, we see a stronger bimodal action distribution. In fact, the bimodal distribution is more pronounced in the interactive interface. This suggests that participants make small adjustments both at the beginning and towards the end of the QS. However, the interactive interface shows more frequent and faster

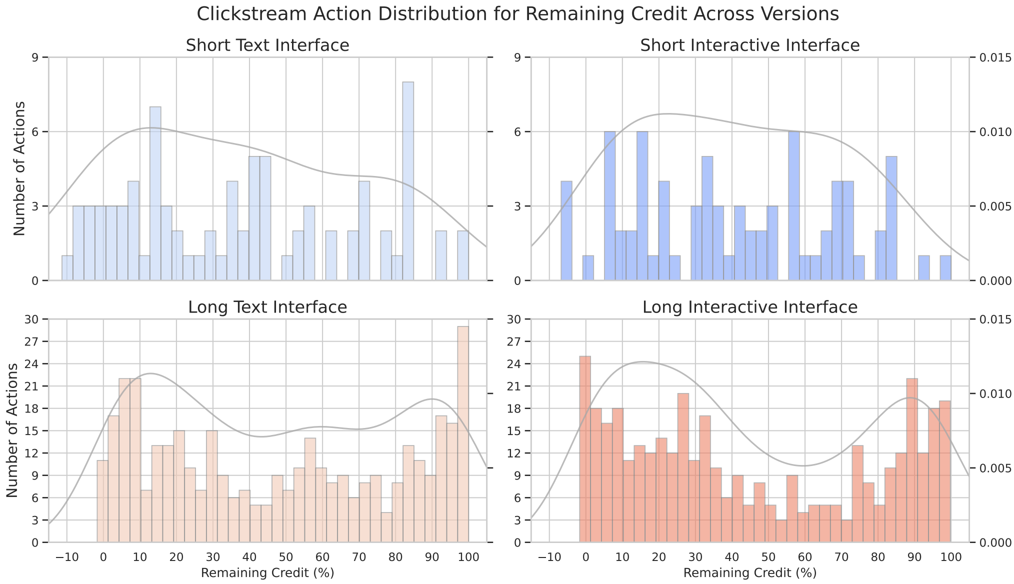

Fig. 19. voting actions across all options (needs to update chart text, remove normalization, and change the dot colors.)

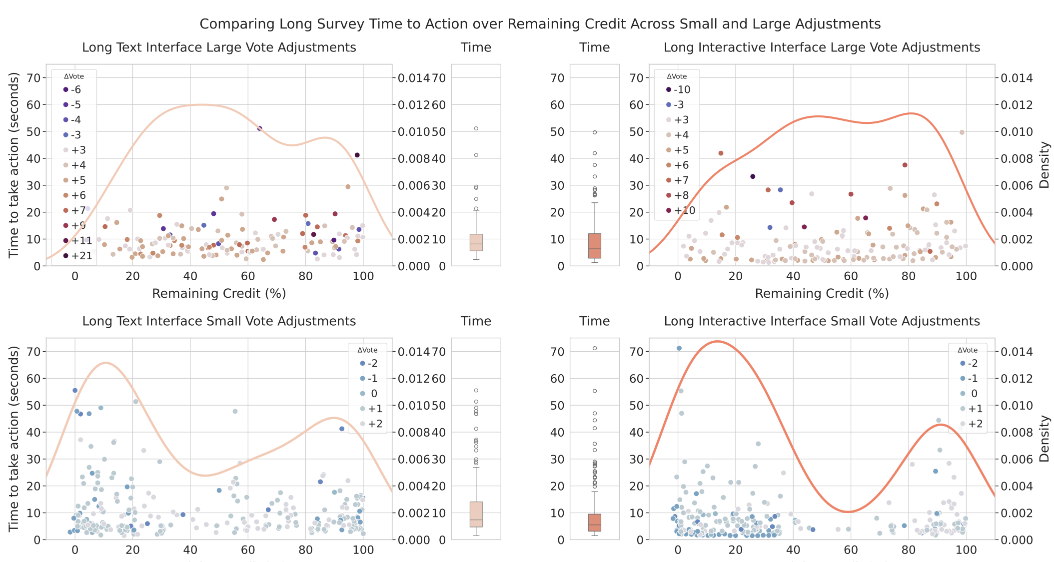

Fig. 20. Breakdown of voting actions (needs to update chart text)

edits towards the end. Visually, dots are more clustered in the long interactive interface for small vote adjustments compared to the long text interface. The Mann-Whitney U Test on the time spent on small vote adjustments showed significant differences ($U = 13037$, $p < 0.001$), with a small effect size (Rank-biserial: 0.227, Cohen's d: 0.195) and a power of 0.381. Based on the KDE plots in the first row of Figure 20, participants also made more large vote adjustments early on that spread more equally compared to the text interface. This indicates that participants had a clearer idea of how to distribute their credits across the options.

In interviews, five participants highlighted the importance of the interface's flexibility and their use of an incremental, iterative approach. All these participants used the interactive interface. While this doesn't mean participants using the text interface didn't take an iterative approach, it highlights that the interactive interface encouraged iterative and incremental updates. As one participant pointed out:

> *I like the fact that it remembers everything that you know. If if you make a mistake, that you don't lose all the work that you've already done. so I think that's very important is that it's an iterative process.*
> *– S019, long interactive interface.*

In summary, the interactive interface allowed participants to better structure their preferences and make faster iterative adjustments, as designed based on the differentiation and consolidation theory. In other words, we show *different* voting behaviors presented across long text and interactive interface, hence **rejecting** the alternative plausible explaination on the hightened cognitive load in the long interactive interface due to a pure increase of cognitive load Due to interactivity, hence further concluding that the interactive interface prevents satisficing from cognitive overload in long QS.

7 Discussion and Future Works

This study aims to propose an interactive interface for QS and understand how the number of survey options and interface influences individuals' cognitive load and behaviors. Our results, presented in section **??**, revealed that longer surveys did not increase cognitive load among participants. We further analyzed the sources of cognitive load and identified different causes across several dimensions. Participants using the interactive interface demonstrated more strategic planning and holistic thinking compared to those using the text-based interface, who focused more on operational tasks. Additionally, the behavioral analysis presented in section **??** showed that participants using the long interactive interface made more frequent, small, iterative updates, indicating a shift in their cognitive load focus.

In the discussion section, we explore three key topics: first, we explore specific interactive interface elements that influenced participant behaviors and their relation to bounded rationality. Next, we examine how participants built their preferences and how direct manipulation within the interface supported them. Finally, we discuss how the interface design mitigated challenges of quadratic mechanisms and identifies remaining issues. We provide recommendations for using this tool and propose design improvements for future development.

7.1 Bounded rationality and interface design

One core repeated theme that emerged throughout participants' responses during the interview relates to bounded rationality. Bounded rationality defined by Simon [45] refers to the idea that individuals' cognitive limitations limited one's ability to use and process all available information, leading to a suboptimal resolution when decision making. When participants respond to a QS, they are faced with multiple options presented on the quadratic survey as well as the abundance of budget. Since the remaining budget translates to possible votes one can select to apply to an option, this adds additional numbers of decisions to make. Even though the drop-down menu showing all possible pre-calculated vote-credit values was a relief for a few participants so they do not need to search for the bounds, this sea of decision-making requires participants to recall and scramble information at once, which is extremely difficult. The byproduct of bounded rationality often translates to individuals satisficing behaviors [90].

> *So I did say, Okay, you know, you thought of enough things, you know, and so it wasn't the most effort I could put in because again, that would have been diminishing returns. I tried to think of enough things that I could make, make a meaningful decision and then move on. [. . .] I think that that's just not a realistic expectation (to be perfect), but I felt satisfied. [. . .] I felt like that (the response) was satisfied, but not perfect. Cause perfect is not a reality.*
>
> *– S036, short text interface.*

Participant expressed their bounded rationality and their decision to satisfice, making *good enough* and not *optimal* decisions.

Cognitive overload also encouraged individuals to create heuristics [91] and over reliance on defaults [60]. Thus, the design of showing one option at a time in the interactive interface lowers the possibility of participants being influenced by the default positions of options or apply heruisitcs to a narrowing set of options and allowed thoughtful reflection to think about their attitude toward that option.

> *Like, at the moment (during organization), when it gives you, like, rank it if it's positive or neutral or negative [. . .] it gives you time to just focus on that single thing and rank it based on how you feel at that moment.*
>
> *– S013, short interactive interface.*

It is important to note that bounded rationality aims not to critique or exploit possible biases but to emphasize the importance of designing interface interventions to prevent survey respondents from making decisions that differ from their true preferences. For example, problem decomposition [92] and dimension reduction is a strategic approach when individuals face cognitive overload. Several participants would create a two axis groupings, despite the experiment group they are in. Participants would have categories that cluster similar topics (i.e., all topics related to health vs. humanitarian) and categories that depict the positivity of their preference (i.e., positive vs. negative). The different between experiment condition only lies in whether these groupings are possible to represent on the interface.

> *Honestly, if medical research [. . .] I think if it was the first option, the first thing I saw, I probably would have given it more [. . .] because medical research [. . .] to me this seems like the most important, but I think if . . . if it was the first one I saw, I think it would automatically gave it a lot more.*
>
> *– S003, short text interface.*

The influence of bounded rationality highlights how critical and beneficial organization on the interface is. Many participants (N=7) who responded to QS using the interactive interface expressed the helpfulness of the organization phase proactively when asked what they liked about the interface in general. In fact, half of the participants (N=5) in the long interactive interface group expressed such an opinion. Multiple participants (N=4, 3 from the long interactive interface group) felt that the upfront introduction of all the topics allowed them to process and think about the full picture, thereby digesting all the information more comprehensively.

> *I would say that (the interface) definitely (supported me), by being able to have a preliminary categorization of all the topics. First, it introduced me to all the topics, so that I can think about them like I can just kind of leave it there in my head space to think about and process [. . .] So being able to digest all the information prior to actually allocating the budget or completing the quadratic survey.*
>
> *– S009, long interactive interface.*

Participants (N=4, 2 from the long interactive interface group) mentioned that organization support helped them to allot the intensity of votes by helping them focus and prioritize options through ranking. This exercise allows them to follow a clear decision-making process that avoids confusion.

> *If I had to choose a number like that in the beginning. That would have been really bad, but positive, neutral, negative. That was good enough.*
>
> *– S016, long interactive interface.*

> *I think ... ranking at the beginning one's impression towards these issues helps to like determine how many votes should be put towards them.*
>
> *– S002, short interactive interface.*

Conversly, participants using the text-based interface requested for organizational features. Almost half of the participants (N=4) using the long text interface expressed a desire for features that can help reduce the decision space when responding to the QS.

> *If anything, I think I would like to be able to like, click and drag the categories themselves so I could maybe reorder them to like my priorities.*
>
> *– S025, long interactive interface.*

> *Because with this many (options), especially when I'm thinking ... Ok, where was (the option) ... Where was (the option) you know? Oh, that's right. Maybe I could give another up another upvote to the, you know whatever [...]*
>
> *– S028, long interactive interface.*

In summary, individual's bounded rationality encouraged participants to exhibit <u>satisficing</u> behaviors, <u>heuristics</u>, and <u>defaults</u> when responding to QS. By showing all options upfront, one-at-a-time, and repositioning options based on participant's rough preferences prevented participants from using defaults and heuristics. The two-phase organization actively scaffolds participant's decision making process supporting efficience<u>problem decomposition</u> and <u>dimension reduction</u>. Together, these elements in the interactive interface design prevented <u>satisficing</u> behaviors and supported participants in making more informed decisions through a more strategic planning and holistic thinking process.

7.2 Construction of Preference on QS

When completing QS, deciding the number of votes for one QS option fits squarely into Lichtenstein and Slovic [17]'s characteristic of difficult decisions. Svenson [18]'s differentiation and consolidation theory explains how participants behave and quote. Recall that the theory states that decision making contains a differentiation stage involving identifying differences and eliminating less favorable alternatives, while the consolidation stage strengthens commitment to the chosen option. Hence, participants decompose options into categories, effectively reducing the decision dimension to mitigate difficulties.

Participants started by constructing preferences in situ, especially regarding options they had not thought about:

> *I mean, it's not necessarily a challenge, but it's interesting to see: 'Oh, there are other aspects that I never care about.' And actually ... some people care <an option>. Sure. Why? Why (should) I spend money on that? That's the first thought that comes to mind.*
>
> *– S037, long interactive interface*

During this process, participants try to identify differences between options and differentiate. Hence, we observe the two axis groupings. The two-phase interactive interface effectively facilitated the expression of at least one dimension. Participants without such support expressed difficulty:

> *If anything, I think I would like to be able to like, click and drag the categories themselves so I could maybe reorder them to like my priorities. And so I could maybe make that like a descending or ascending like list of like importance. [...] if I could pull that up to the top, say myself like click and drag it up there, I think then I would stack the things I think it would affect under it. So like, I would put then, like youth, pro-education programs and adult education and early childhood programs and kinda stack those altogether. [...] I would*

kind of make myself categories and subcategories out of this list . . . If I could organize it. – S025, long text interface.

The ability to drag-and-drop options in the interactive interface blends this differentiation process into the consolidation phase. For example, placing options next to one another facilitated fine-grain differentiation:

I think the system was actually really helpful because I could just drag them. [. . .] Because when I was unsure, because if I couldn't drag them then I couldn't compare 2 options very well like side to side, because this is a pretty long list . . . so if I couldn't drag it, then I would have a harder time organizing my thoughts, whereas with the dragging feature I can really compare them, I can drag this one up here, and then compare it to the top one versus not being able to track it at all. – S039, long interactive interface.

We also observe participants differentiating and consolidating through their behavior. Recall the bi-modal behavior in Figure 20, since participants in the interactive interface had completed initial differentiation early in the voting process, they assign votes to highlight these differences. Conversely, participants in the text interface made larger updates of the votes slightly later. As participants began consolidating their preferences, participants in the long interactive interface maintain their mental capacity to make fine-grain adjustments given faster iterations and small vote updates. Hence, we see a stronger bimodal pattern indicating the two stages in the long interactive interface, compared to the long text interface. This is less significant in the short QS likely due to the reduced complexity [6]. One participant explicitly expressed their strategy:

I only start from the positive one [. . .] I finish everything . . . and then I move to the second part (the netural box). [. . .] I want to focus on these and make sure that resources are at least they get the attention they want. And if there's surplus and they can move to the second part

– S037, long interactive interface

As participants begin consolidating their preferences using votes, drag-and-drop are occasionally used to reflect on their expressed preferences. In other words, reflecting and reassuring their decisions. When asking `S021` why they would drag-and-drop an option after voting, the participant responded:

So I guess to see what my ranking look like . . . and see if I could give more money or not.

– S021, long interactive interface.

One participant confirmed this mapping by describing their approach to QS on the long interactive interface, highlighting the differentiation, the consolidation, and reflection:

[. . .] this (option) is something that's really important to me . . . So I had the flexibility to move it to positive. So just having the kind of like shift in perception. [. . .] especially because when I was doing categorization in the first step, [. . .] what I thought about it in the moment. [. . .] In the second step there was a shift in my perception of the issue just reflecting. So being able to change. That was really nice as well.

– S009, long interactive interface.

In summary, participants construct their preferences as they complete QS. We observed behaviors and qualitative insights that align to the differentiation and consolidation process in decision making. Our interface scaffolded many of the differentiation stages through pre-voting organization and some consolidation phases through drag-and-drop. Thus, this explains how the two-phase approach supports preference construction to yield effective QS responses.

7.3 Opportunities for better budget management

Budget management is a recurring theme in participant interviews. While they appreciated the automatic calculation feature in modern QV interfaces, we identified three challenges for future QS interfaces: *cognitive load*, *the cold-start problem*, and *navigating between budget, votes, and outcome*.

[6]We show in Appendix **??** that short interfaces exhibits the same bimodal behaviors but less obvious.

7.3.1 Automatic calculation is critical. Over one-third of participants ($N = 14$) from all four experiment conditions emphasized the importance of automated calculation for deriving costs and tracking expenditures. For example:

> *I really like having the costs of all the votes displayed. When you select the dropdown menu and ranked in order.*
>
> *– S002, short interactive interface, deriving cost*

> *I thought I have [. . .] (to) do all the numbers or calculation myself as a part of checking my ability of doing mathematics. But I guess you have taken care of that really well, so I could really really see that how much credit has left, and [. . .] how well I should allocate [. . .] I said that credit summary to be very specific. The credit summary section was really wonderful in doing all the calculation on that end.*
>
> *– S005, long text interface, keeping track of spent*

These quotes marked the importance that QS must be facilitated by computer-supported interfaces.

7.3.2 Cognitive load from budget management. Section 5 reveals that participants experienced cognitive load due to budget management. Behavioral economists like Shah et al. [88] believe that values and careful decision-making are derived from limited resources, which introduce higher cognitive load. Prospect theory [93] highlights the higher negative value of *perceived* utility when cuts must be made. This evidence underscores the heightened cognitive load participants experience when managing their budget. Our interface lacks tools to mitigate this, making it a crucial area for future work.

7.3.3 The coldstart problem. We notice from the study that one of the biggest challenges for participants is deciding 'how many votes' to start with. This challenge pertains to the initial vote, not the relative vote. Some participants began by equally distributing their credits to all options and then made adjustments. Others established 1, 2, and 3 votes as starting points. A small handful surprisingly used the tutorial's example of 4 upvotes as their anchor.

This arbitrary voting decision echoes discussions in prior literature about the existence of an absolute value for individuals. Coherent arbitrariness [94], similar to the anchoring effect in marketing, refers to participants' willingness to allocate votes, which can be influenced by an arbitrary value. However, the ordinal utility remains intact among the set of preferences.

This challenge remains an open question, and future research can explore possibilities to scale ordinal utility to map it to individual preferences without biasing participants.

7.3.4 Navigating Between Budget, Votes, and Actual Impact. The third challenge refers to participants' confusion between budget, votes, and actual outcomes. While participants are clear with the definitions of these elements, it is not clear for them to make effective decisions. One participant stated:

> *[. . .] get rid of the Upvote column or just get rid of the word upvote and just really focus on the money column. Listen. You're an organization or your participant. You have X amount of dollars you need to. You can only distribute X amount of dollars to these these causes. So you have to figure out which ones get the most, which ones don't get as much. [. . .]*
> *Interviewer: So when you're operating this interface. Do you feel that the more votes you're giving to a cause you're actually spending more on it?*
> *Yeah.*
>
> *– S003, short text interface.*

Recall that this survey aims to assist community organizers in distributing resources to a societal cause. This participant decided to 'skip' over the quadratic formulation and the concept that their votes are governed by the quadratic formulation, drawing a direct translation between votes and the resources to which community organizers ought to contribute. While this does not invalidate the power of the quadratic mechanism, it builds frustration and friction for participants to construct a clear picture of how to make voting decisions.

HS: This para has me confused. What are you trying to say? Budget-related sources draw across mental demand, temporal demand, preference demand, and frustration. These span from making sure to keep within budget to recovering from overbudgeting. While prior scarcity literature [88] believes that values and careful decisions are derived from limited resources, prospect theory [93] also highlights a higher negative value of *perceived* utility for individuals when cuts ought to be made.

These three major challenges do not threaten the integrity of the Quadratic Survey and relevant tools using this mechanism, but as we demonstrated in the results section, across all experiment conditions, the NASA-TLX scales show medium to high cognitive load even for the short, interactive interface. In other words, we believe that the improvement of the Quadratic Survey's ability to elicit more accurate preferences comes at the cost of higher cognitive load.

7.4 QS Usage and Design Recommendations and Future Work

With a deeper understanding of how survey respondents interact with QS and the sources of cognitive load, we recognize that while this interface may not significantly reduce cognitive load, it represents a crucial step toward constructing better interfaces to support individuals responding to QS. In this subsection, we outline usage and design recommendations applicable to all applications using the quadratic mechanism and highlight directions for future work.

7.4.1 Usage Recommendation: QS for Critical Evaluations. Our study highlighted the complex cognitive challenges and in-depth consideration required when ranking and rating options using QS, even in a short survey. Similar to survey respondents needing to make trade-offs across options, researchers and agencies seeking additional insights and alignment with respondent preferences must ensure that survey respondents have the cognitive capacity to complete such surveys rigorously. We recommend designing QS for specific use cases requiring critical evaluations, such as investment decisions or settings where participants have ample time to think and process the survey. For instance, revealing the options ahead of time can aid in preference construction.

7.4.2 Design Recommendations.

Use Organization Phases for Quadratic Mechanism Applications. Our study demonstrated that preference construction can shift from operational to strategic and higher-level causes. An additional organizational phase with direct manipulation capability allows survey respondents to engage in higher-level critical thinking. We believe this approach should extend beyond QS to other ranking-based surveying tools, such as rank-choice voting and constant sum surveys. Further research should examine how implementing such functionality alters survey respondents' mental models.

Facilitate Differentiation through Categorization, Not Ranking. Participants in our study were less inclined to provide a full rank unless necessary. The final 'rank' of option preferences often emerged as a byproduct of their vote allocation, constructed in situ. Therefore, for survey designs to be effective in constructing preferences, it is more important to facilitate differentiation than to focus on direct manipulation solely for fine-tuning. Emphasizing categorization can better support participants in articulating their preferences.

7.4.3 Future Work: Support for Absolute Credit Decision. Deciding the absolute amount of credits in QS is highly demanding. Designing interfaces and interactions that address the cold start challenge and help participants decide the absolute vote value, while considering ways to limit direct influences, remains an open question. Future research should explore innovative solutions to support participants in making these complex decisions effectively.

By implementing these recommendations and pursuing future research directions, we can improve the usability and effectiveness of QS and other quadratic mechanism-powered applications, ultimately aiding respondents in making more informed and accurate decisions.

8 Limitations

9 Conclusion

In this study, we proposed a novel interface for quadratic surveys and studied the cognitive load of survey respondents when using this interface or not across a short and long survey. Our results highlighted that while the introduction or organization phase before conducting the survey did not reduce cognitive load significantly, participants' behaviors had shifted with more engaging and higher-level considerations. We believe that the interactive interface is critical for survey respondents.

A Alternative prototypes for QS

here are some alternatives

B List of Options

We provide the full list of options presented on the survey.

- **Animal Rights, Welfare, and Services:** Protect animals from cruelty, exploitation and other abuses, provide veterinary services and train guide dogs.
- **Wildlife Conservation:** Protect wildlife habitats, including fish, wildlife, and bird refuges and sanctuaries.
- **Zoos and Aquariums:** Support and invest in zoos, aquariums and zoological societies in communities throughout the country.
- **Libraries, Historical Societies and Landmark Preservation:** Support and invest public and specialized libraries, historical societies, historical preservation programs, and historical estates.
- **Museums:** Support and invest in maintaining collections and provide training to practitioners in traditional arts, science, technology, and natural history.
- **Performing Arts:** Support symphonies, orchestras, and other musical groups; ballets and operas; theater groups; arts festivals; and performance halls and cultural centers.
- **Public Broadcasting and Media:** Support public television and radio stations and networks, as well as providing other independent media and communications services to the public.
- **Community Foundations:** Promote giving by managing long-term donor-advised charitable funds for individual givers and distributing those funds to community-based charities over time.
- **Housing and Neighborhood Development:** Lead and finance development projects that invest in and improve communities by providing utility assistance, small business support programs, and other revitalization projects.
- **Jewish Federations:** Focus on a specific geographic region and primarily support Jewish-oriented programs, organizations and activities through grantmaking efforts
- **United Ways:** Identify and resolve community issues through partnerships with schools, government agencies, businesses, and others, with a focus on education, income and health.

- **Adult Education Programs and Services:** Provide opportunities for adults to expand their knowledge in a particular field or discipline, learn English as a second language, or complete their high school education.
- **Early Childhood Programs and Services:** Provide foundation-level learning and literacy for children prior to entering the formal school setting.
- **Education Policy and Reform:** Promote and provide research, policy, and reform of the management of educational institutions, educational systems, and education policy.
- **Scholarship and Financial Support:** Support and enable students to obtain the financial assistance they require to meet their educational and living expenses while in school.
- **Special Education:** Provide services, including placement, programming, instruction, and support for gifted children and youth or those with disabilities requiring modified curricula, teaching methods, or materials.
- **Youth Education Programs and Services:** Provide programming, classroom instruction, and support for school-aged students in various disciplines such as art education, STEM, outward bound learning experiences, and other programs that enhance formal education.
- **Botanical Gardens, Parks, and Nature Centers:** Promote preservation and appreciation of the environment, as well as leading anti-litter, tree planting and other environmental beautification campaigns.
- **Environmental Protection and Conservation:** Develop strategies to combat pollution, promote conservation and sustainable management of land, water, and energy resources, protect land, and improve the efficiency of energy and waste material usage.
- **Diseases, Disorders, and Disciplines:** Seek cures for diseases and disorders or promote specific medical disciplines by providing direct services, advocating for public support and understanding, and supporting targeted medical research.
- **Medical Research:** Devote and invest in efforts on researching causes and cures of disease and developing new treatments.
- **Patient and Family Support:** Support programs and services for family members and patients that are diagnosed with a serious illness, including wish granting programs, camping programs, housing or travel assistance.
- **Treatment and Prevention Services:** Provide direct medical services and educate the public on ways to prevent diseases and reduce health risks.
- **Advocacy and Education:** Support social justice through legal advocacy, social action, and supporting laws and measures that promote reform and protect civil rights, including election reform and tolerance among diverse groups.
- **Development and Relief Services:** Provide medical care and other human services as well as economic, educational, and agricultural development services to people around the world.
- **Humanitarian Relief Supplies:** Specialize in collecting donated medical, food, agriculture, and other supplies and distributing them overseas to those in need.
- **International Peace, Security, and Affairs:** Promote peace and security, cultural and student exchange programs, improve relations between particular countries, provide foreign policy research and advocacy, and United Nations-related organizations.
- **Religious Activities:** Support and promote various faiths.
- **Religious Media and Broadcasting:** Support organizations of all faiths that produce and distribute religious programming, literature, and other communications.
- **Non-Medical Science & Technology Research:** Support research and services in a variety of scientific disciplines, advancing knowledge and understanding of areas such as energy efficiency, environmental and trade policies, and agricultural sustainability.

- **Social and Public Policy Research:** Support economic and social issues impacting our country today, educate the public, and influence policy regarding healthcare, employment rights, taxation, and other civic ventures.

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