# Beyond Static Labels: Unpacking Nutrition Comprehension in the Digital Age


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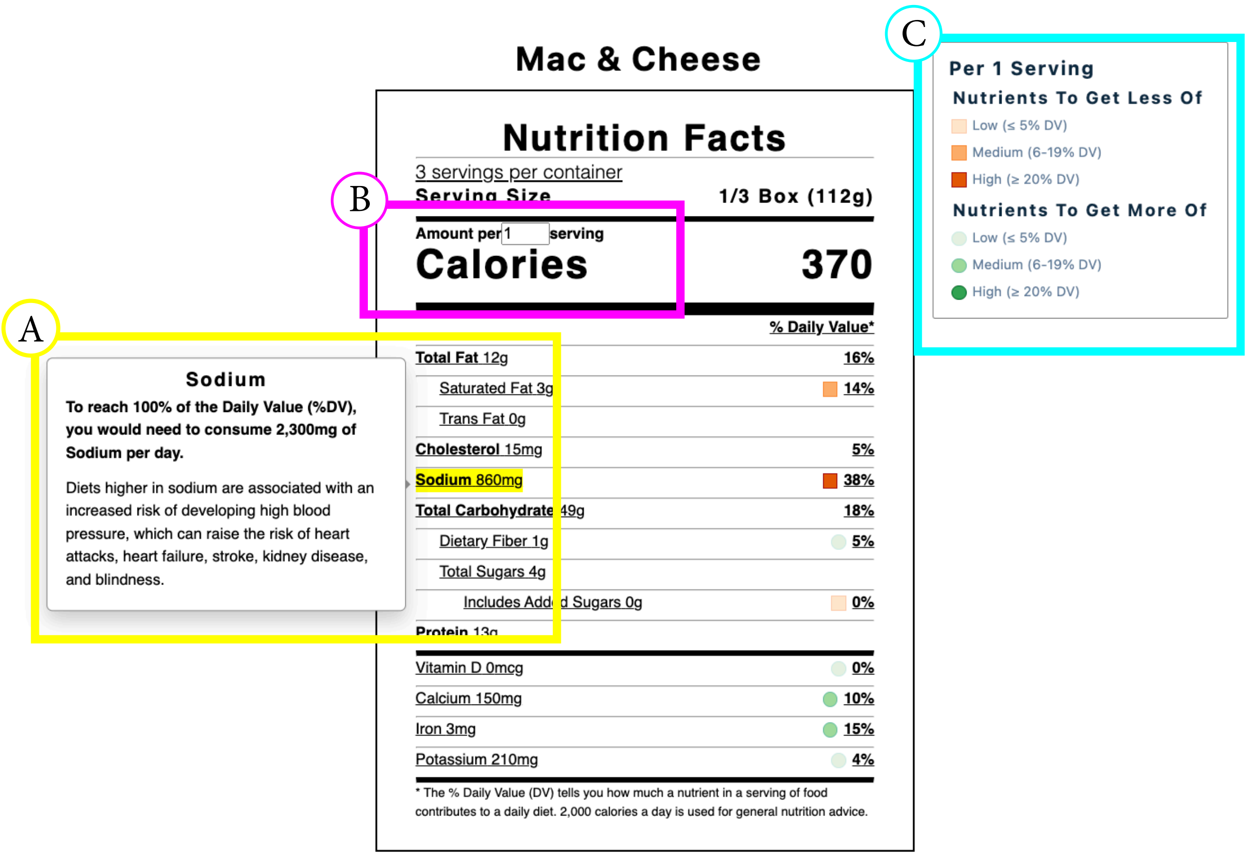


**Figure 1: Interactive Nutrition Label with Key Features Highlighted. A) An example of the details-on-demand information activated by hovering over underlined text. B) The calculator feature for customizing serving sizes. C) The visual encoding legend for understanding nutrient encodings. Details on the design can be found in Section 3.**


## ABSTRACT

Understanding nutrition labels remains challenging for consumers; however, digital shopping environments offer opportunities to explore how interactive nutrition labels may be used to enhance




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comprehension. We conducted an A/B study with 24 participants, comparing their ability to interpret and apply nutrition information using conventional, static labels versus interactive labels. We evaluated interactive nutrition labels' impact through quantitative metrics and qualitative insights from interviews and think-aloud sessions. Our findings reveal a statistically significant improvement in assessing nutrient amounts and interpreting numerical information when users engage with interactive labels. These results underscore the potential interactivity has on promoting public understanding of nutritional content and highlight opportunities for refinement. Based on our findings, we propose new design directions and discuss technology's role in making nutrition labels more effective for decision-making and nutrition education.

## CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

## KEYWORDS

Health management, nutrition label, interactive label

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## 1 INTRODUCTION

The rising levels of obesity and diet-centric health issues have made effective nutrition education an urgent need [14, 48, 62]. A vital facet of nutrition education is *nutrition literacy*, which refers to the capacity to obtain, process, and understand basic nutrition information and services needed to make appropriate health decisions [10, 71]. Poor nutrition literacy can lead to suboptimal food choices, contributing to unhealthy lifestyles and various diet-related health problems [65, 67]. Nutrition labels are critical for consumers to gauge a food product's nutritional value [21, 25]. Nevertheless, the utility of nutrition labels, albeit widely acknowledged [25, 39, 64], often demands specialized knowledge and can be ambiguous, causing consumer confusion [15, 18, 29]. More specifically, research has shown that consumers often find it challenging to interpret the quantitative information on nutrition labels [15, 18]. With society increasingly focused on health and wellness, there is an imperative to improve the dissemination of nutritional information not only in retail environments but also in educational settings, healthcare facilities, and public health initiatives, especially in ways that can enhance nutrition literacy across diverse populations.

In the wake of the COVID-19-induced surge in online grocery shopping [27, 54], interactive nutrition labels offer a new avenue for enhancing nutrition education. Unlike their traditional counterparts, which are constrained by the physical space on food packaging, interactive labels offer extensive design possibilities for digital environments [5, 13]. More specifically, technology increasingly mediates our interactions with food [3], and can be utilized to support better informed food choices [7]. This development aligns with a broader trend in healthcare and wellness, where interactive platforms and digital tools have been successfully employed to enhance health understanding and promote positive health behaviors [50, 59].

Given the challenges identified in nutrition science—namely, consumers' difficulties with interpreting recommended daily amounts, percent daily values, serving sizes, or other forms of reference information [35, 37, 38, 57]—we designed an interactive nutrition label featuring hover-over context, dynamic serving size adjustment, and visual encodings, all explicitly designed to help users overcome numeracy challenges and reduce confusion, thereby enhancing overall comprehension. To explore the potential of interactive labels, we framed three research questions to guide our investigation:

- **RQ1: To what extent does an interactive nutrition label enhance a user's comprehension of nutritional information?** An improved understanding of nutritional information can give consumers a more accurate perception of what they consume, potentially steering them toward better dietary decisions. Here, we explore how our three interactive elements may support consumer comprehension.
- **RQ2: How does an interactive label facilitate product comparisons and related calculations within the same category?** Given the plethora of options available in the market, enabling efficient product comparisons can equip consumers to make more informed and health-conscious choices. Although our interactive label was primarily designed to enhance the evaluation of individual products, we also aimed to understand its effectiveness in aiding consumers with product comparisons.
- **RQ3: How do users perceive the utility of an interactive nutrition label?** Through a think-aloud protocol and brief semi-structured interviews, we gathered participants' perspectives to inform potential enhancements in design and to gauge broader acceptance of interactive labels.

We addressed our research questions by conducting an A/B study involving 24 participants. To quantitatively assess the effectiveness of the interactive label, we measured participants' performance on tasks that included assessing nutrient amounts, performing mathematical calculations based on the label, and comparing products. To understand participants' thought processes, we conducted the experiment as a "think-aloud" study, where participants were asked to verbalize their thoughts while completing the tasks. In addition, we conducted brief semi-structured interviews to gather qualitative data on their preferences and perceptions regarding their assigned label. Additionally, open-ended questions were posed between tasks, focusing on each product's positive and negative aspects and participants' assessments of product healthfulness.

This comprehensive approach allowed us to capture a nuanced understanding of how the label was used across different decision-making contexts that could inform future design improvements. Our results indicate that the interactive label significantly aided participants in assessing nutrient amounts and successfully completing questions that required mathematical calculations. However, while interactive labels showed promise, they were not without limitations, offering valuable insights for future design improvements. Our contributions are twofold. First, we demonstrate how interactive elements can enhance consumer interpretation of nutrition labels. Second, we highlight opportunities as design considerations for leveraging digital labels to improve nutrition literacy.

## 2 RELATED WORK

We next discuss prior work on nutrition label comprehension and technology's role in advancing the dissemination of food-related information.

### 2.1 Comprehension of Nutrition Labels

Nutrition labels are provided on food products to help consumers understand the nutritional quality and to influence purchase decisions regarding diet and health [40]. The U.S. Food and Drug Administration (FDA) implemented the nutrition facts label as a policy tool to provide nutrition information [20]. As a result, researchers have found that the nutrition label is the top source consumers rely on for information regarding the healthfulness of a food product [58, 70]. A positive correlation has been shown between the usage of nutrition labels and health benefits among consumers [45, 68]. However, nearly half of American adults have difficulty understanding and using the information on nutrition and other health labels, leaving the labels highly underutilized in promoting health and well-being [24, 38, 69].

Nutrition literacy is a necessity to utilize nutrition information on labels to make appropriate health decisions [33]. Studies have shown that an increased ability to comprehend nutrition information on foods can contribute to better health [63]. Consumers understand some information on the nutrition label; however, they generally find it confusing and challenging to interpret [1, 15, 26, 38, 69]. More specifically, studies have found that consumers tend to have difficulty when being presented with quantitative information on nutrition labels, such as recommended daily amounts, percent daily values, serving sizes, or other forms of reference information [35, 37, 38, 57]. As the complexity of dietary tasks escalates, the efficacy of gleaning insights from nutrition labels decreases, especially when mathematical calculations are required [15]. Consumers tend to make the most mistakes when estimating the contribution a food product has to their daily nutrient requirements [15]. Indeed, Levy et al. found that consumers could follow nutrition labels to lower their daily fat intake [36]; however, consumers did not fully understand the percent daily value or accurately report how to use it. In a separate study by Levy et al., it was found that only 20% of participants were able to accurately determine how a product's nutrient levels contributed to different serving sizes, a task requiring more complex mathematical calculations [35].

Previous studies have addressed ways to help simplify components of the nutrition facts label to improve nutrition literacy [63]. Studies suggest that front-of-package (FOP) label designs that incorporate color and the words "high," "medium," and "low" to describe nutrients can assist consumers in selecting healthy foods [26, 66, 69]. Cowburn et al. state that format changes in the nutrition label, including the addition of interpretational aids, such as verbal descriptors, may help consumers with more complex tasks. Verbal descriptors include using verbal banding information alongside numerical information and bar charts [15]. In our study, we implement interactive features directly into a nutrition label to support consumers in understanding and interpreting the label. We aimed to explore the potential impact of these interactive features by understanding if participants still make these same mistakes when exposed to an interactive nutrition label compared to a static label.

### 2.2 Technology and Food Information

Technology has increasingly played a pivotal role in our everyday interactions with food [7], which can be partly attributable to the growing human-food interaction (HFI) field [3]. This field spans a range of applications, from meal recommendation algorithms [72] and nutritional tracking systems [61] to persuasive games aimed at modifying eating habits [32]. These systems contribute to users' comprehension and engagement with food-related information, emphasizing how technology can support healthier choices [6–8].

Within this technological landscape, visual encodings stand out as particularly effective tools. The use of visual aids to represent nutritional data, such as bullet graphs [13], pie charts [41], multidimensional pixel designs [17], and glyphs [41, 55] has been proven to enhance user comprehension. For instance, Coelho's research suggested bar charts as more effective than pie charts in conveying nutrient information [13], while Riehmann employed glyph-based characters to help children understand nutritional values [55].

In tandem with these efforts, real-time feedback mechanisms have also supported users to understand complex food information better. Technologies like the *Health Shelf* by Bedi et al. offer immediate nutritional evaluations to aid in product comparison [5], while Mulrooney et al.'s scanning device helps consumers identify suitable food items based on their dietary needs [43]. Ahn et al. took this further by incorporating augmented reality (AR) for an even more streamlined shopping experience [2]. However, it is worth noting that some of these systems, such as Dawson's data visualization tool *NUT*, still lack evidence for their effectiveness in real-world applications [17].

The domain of persuasive games represents another interesting angle, employing behavioral psychology techniques to make choosing healthier food options more engaging [28, 49, 51]. These various technological avenues collectively contribute to a more informed and healthier food selection process. Our study builds on these existing efforts by exploring how interactive features can enhance user comprehension of nutrition labels.

## 3 INTERACTIVE LABEL OVERVIEW

Our control group was presented with a conventional static nutrition label. However, for the experimental stimuli, we designed an interactive nutrition label that included three features specifically developed to assist users in performing the most common tasks associated with nutrition labels [15]: identifying nutrient quantities, assessing what constitutes low or high levels of a particular nutrient, and calculating nutrient quantities in a given serving size.

The first feature provided hoverable details-on-demand [60] for each nutritional element, including the servings per container, the name of the nutrient, and the percent daily values. These details were supplemented with information from the FDA [19]. (See the yellow-highlighted area in Figure 1A for an example of the details-on-demand feature.)

The second feature we implemented was an interactive calculator that let users adjust the 'amount per serving' on a nutrition label. When users altered this amount, all corresponding nutritional data—including calories, nutrient quantities in grams, milligrams, or micrograms, and the percentage of daily recommended values—dynamically updated to reflect the new 'amount per serving'. (See the pink-highlighted area in Figure 1B for the interactive calculator feature.)

The third feature was a legend employing visual encodings. Following Munzner et al.'s guidelines for visual encodings [44], we encoded shape and color hue to categorize the *nutrients of public health concern* as defined by the Dietary Guidelines for Americans (DGA) [46]. The DGA recommends increasing consumption of specific nutrients, including dietary fiber, vitamin D, calcium, iron, and potassium, while advising limitations on others like added sugars, saturated fat, and sodium [46]. To differentiate between these two categories of nutrients, we used shape encodings: squares to signify nutrients to limit and circles for nutrients to prioritize. Furthermore, we adopted a color scheme akin to the 'traffic-light' nutrition labeling system [56], using shades of red and green. Specifically, red squares were employed to indicate nutrients that should be limited, while green circles denoted nutrients that should be increased. In addition, we utilized color saturation to represent percent daily value as a sequential variable [44], where varying levels of saturation corresponded to low (≤ 5%), medium (6% – 19%), and high (≥ 20%) percent daily values. A persistent legend was made available so that consumers could always reference the visual encodings. (Refer to the blue-highlighted section in Figure 1C for details on the visual encoding legend.)

## 4 STUDY DESIGN

We investigated how interactive nutrition labels can support participants' ability to interpret information from the the nutrition label. We employed a between-subjects A/B experimental design to assess the impact of an interactive label within a controlled environment setting. Participants were randomly divided into two groups. The control group (Group A) viewed a conventional, static nutrition label, akin to what one would typically find online looking at a product's nutrition label. In contrast, the experimental group (Group B) interacted with the interactive nutrition label that we designed. We conducted the experiment as a think-aloud study, wherein participants were asked to verbalize their thought processes while completing the tasks, allowing us to examine participants' thought processes and identify potential usability issues. This was supplemented with a brief post-experimental interview to gather their experiences and impressions.

### 4.1 Participants

Participants were recruited through multiple channels. Physical flyers were disseminated at community events, and digital versions were circulated via email to various community and campus organizations. Interested individuals could secure an appointment by scanning a QR code on the flyer. We opted not to impose any specific inclusion or exclusion criteria to capture a broad range of perspectives and enhance the generalizability of our findings, so the only recruitment criterion was that participants had to be at least 18 years old. As part of our commitment to accessibility, our demographics survey included a question asking participants if they were colorblind. This was to ensure that anyone who needed a more accessible version of the study, especially given the use of red and green in our labels, could be accommodated. No participants reported being colorblind. The sample consisted of 24 participants (*M*=35.8 years, *SD*=16.0 years), equally divided between the two experimental conditions: Group A, which interacted with the static label, and Group B, which was exposed to the interactive label. Table 1 provides a summary of participants' self-reported demographics.

| | | n *(%)* |
|---|---|---|
| **Gender** | Women | 16 *(67%)* |
| | Men | 8 *(33%)* |
| **Age** | 18-29 | 14 *(58%)* |
| | 30-39 | 2 *(8%)* |
| | 40-49 | 1 *(4%)* |
| | 50-59 | 4 *(17%)* |
| | 60+ | 3 *(13%)* |
| **Race / Ethnicity** | African American | 9 *(38%)* |
| | White | 4 *(17%)* |
| | Hispanic or Latino | 5 *(21%)* |
| | Asian | 2 *(8%)* |
| | Multiracial | 3 *(13%)* |
| **Highest Education Attained** | Less than High School | 2 *(8%)* |
| | Some College, No Degree | 5 *(21%)* |
| | Associate's Degree | 3 *(13%)* |
| | Bachelor's Degree | 9 *(38%)* |
| | Master's Degree | 3 *(13%)* |
| | Doctorate or PhD | 2 *(8%)* |

**Table 1: Participants Self-Reported Demographics.**

In addition to demographic information, we also collected participants' nutrition behaviors by asking three questions using Likert scales: their frequency of using nutrition labels when choosing food products, their confidence in understanding these labels, and the importance of these labels in influencing their food choices. The distribution of responses to these questions is summarized in Figure 2. While we assessed participant's familiarity with nutrition labels, we did not consider individual dietary preferences and sensitivities, such as allergens. These factors are important for assessing a specific product; however, they introduce a level of specificity beyond the scope of our primary objective–evaluating nutrition label comprehension.

To ensure a balanced representation in the study, participants were evenly distributed across the two groups, maintaining a proportional mix of individuals from the various communities we recruited from. This balance is further evidenced by a statistical


**Figure 2: Comparative analysis of participant responses on a Likert scale for nutrition behavior. Responses reflect confidence in understanding labels, importance of labels in food choices, and frequency of label use. Scale specifics are elaborated in the Supplemental Materials.**

analysis comparing the two groups across age, gender, race, education level, and self-reported nutrition behaviors. The detailed results of this analysis, demonstrating no significant differences between the groups, are presented in the Appendix A. Participants were compensated with $10 for their time and involvement.

## 4.2 Tasks

Three tasks were modified from extant nutrition science literature [24, 37] to evaluate how interactivity supported nutrition label interpretation:

- **Understanding Nutrient Amounts (*UND*)**: We modified the NUTRICLAIM task originally developed by Levy et al. [37]. Instead of presenting participants with food claims that labeled nutrients as low, medium, or high and asking them to evaluate the truthfulness of these claims, we took a more straightforward approach. We asked participants to assess the levels of each nutrient in a food product as either low, medium, high, or state if they were unsure. This modification was designed to explore whether participants in Group B would utilize the visual encodings provided on the label to aid in their assessments. An example question in this task would be: *“Considering the nutritional label provided, describe the level of each nutrient—low, medium, high, or unsure—for one serving of this particular product.”*
- **Nutrition Numeracy (*NUM*)**: We adapted questions from the Food Label and Numeracy domain of the Nutrition Literacy Assessment Instrument (NLit) [24] to specifically evaluate the effectiveness of our calculator feature. This task was divided into two sets of questions, each focusing on different aspects of nutritional calculations. This was done to ensure we weren’t merely testing the user interface, but also assessing its impact on on various questions that require numeracy skills. The first set consisted of three questions that provided participants with a given amount of servings and then asked them to calculate the percent daily value or the total grams of a specific nutrient. An example question from this set is: *“If you ate all the servings in this product, how many Calories would you have consumed?”* The second set of three questions presented scenarios where participants needed to determine the servings required to reach a certain nutrient limit. For instance, one question asked: *“How many servings of this product would you need to eat to get 10mg of Iron?”* Unlike the original NLit [24], which used multiple-choice questions, we opted for text box inputs. This allowed participants to make educated guesses when uncertain, providing a more nuanced insight into their understanding.
- **Product Comparison (*COM*)**: The product comparison task was designed to evaluate participants’ ability to compare nutritional information across two different products from the same product category (i.e., comparing two different bags of chips). This task consisted of five questions that prompted participants to make side-by-side comparisons involving various nutrients. Questions ranged from straightforward comparisons of the entire product to more complex assessments involving half of the servings in a product. For example, one question was, *“Which has fewer grams of Sodium: $\frac{1}{2}$ of all the servings in Chips A or all of the servings in Chips B?”* Additionally, the task included questions where participants had to evaluate combinations of both products, requiring them to engage in multi-step reasoning to determine which mix of servings yielded the desired nutrient intake. This task evaluated participants’ ability to apply the information from the interactive labels in complex, real-world scenarios, such as comparing multiple food products. This task was designed to test if interactive features like the calculator and visual cues enhanced decision-making accuracy.

*4.2.1 Objective Metric Measures.* In this section, we describe how we measured *accuracy* as performance. For **UND**, **NUM**, and **COM** tasks, we adopted a binary scoring system: correct responses were assigned a score of 1, and incorrect responses received a score of 0. The accuracy for each task was then calculated by dividing the total number of correct responses by the total number of questions in each task, converting the result into a percentage to represent accuracy per task.

For the **UND** task, we adopted the FDA’s guidelines for classifying nutrient levels based on their percent of the recommended daily value [20]. Specifically, levels were considered low ($\leq 5\%$), medium ($6\% - 19\%$), or high ($\geq 20\%$). An answer was deemed correct if the participant’s assessment aligned with these FDA classifications. To focus on the quality of the answers provided, responses marked as ‘unsure’ were excluded from the analysis.

In the **NUM** task, we used a text input box instead of multiple-choice options to allow participants to make their best guess. We considered answers to be correct if they deviated by no more than two servings from the exact answer, rounded to the nearest tenth. For instance, if the correct answer was 9.2 servings, responses between 7.2 and 11.2 were accepted as correct. This criterion also applied to questions where the amount of servings was provided. Answers that deviated substantially from a reasonable range, were excluded from the data analysis.

In the **COM** task, participants were faced with two choices, giving them a 50% chance of answering each question correctly.

While time is often an important performance metric, we chose not to include it in our study. Given that participants vary in their verbal responses and willingness to "think aloud," the additional time spent articulating thoughts could introduce unwanted variability, skewing any time-based measurements [42].

## 4.3 Semi-Structured Interviews

After completing the tasks, each participant engaged in a brief semi-structured interview to collect qualitative insights into their experience with their assigned nutritional label. Conducted as an extension of the think-aloud study, the interview aimed to complement the objective metrics by offering a more comprehensive understanding of participants' interactions with both traditional and interactive nutrition labels. All questions can be found in Supplemental Materials.

## 4.4 Experiment Design

A controlled experiment allowed us to focus on assessing the interactive labels' effectiveness in enhancing understanding of nutritional information while gathering helpful usability information. Additionally, the design and context of the interactive label, tailored for digital online use, were closely aligned with the experimental environment. This controlled experimental setup effectively isolated the study from the numerous confounding variables that typically arise in real-world scenarios. By carefully designing tasks and anonymizing products, we prioritized a clear assessment of label interaction over potential biases such as brand loyalty or product familiarity. The study employed a between-subjects design with a singular independent variable: the type of nutrition label presented. Participants were either assigned to a static, traditional nutrition label (Group A) or an interactive, dynamic nutrition label (Group B).

All participants were exposed to nutrition labels for three different types of food products—cake, milk, and cereal—sequentially, regardless of their assigned label group. Our selection of food categories was diverse, ranging from whole foods, such as milk, to highly-processed options, such as cake. This variety included foods with both healthy and less healthy alternatives, exemplified by the difference between whole grain and high-sugar cereals. This range was essential to evaluate the effectiveness of interactive labels in enabling consumers to discern healthfulness from nutritional information alone. We excluded categories with minimal nutritional variation, such as meats and vegetables, to avoid biased assessments influenced by common perceptions of these foods as universally healthy. This decision aligns with our aim to present a realistic and varied array of choices, akin to what consumers encounter.

Following the approach of previous studies in this area [37, 38], we kept the brand, product name, additional details, and the specific subtype of the product anonymous; participants only knew the general category (e.g., "milk"). This approach allowed us to focus on the participants' ability to interpret quantitative data without assumptions arising from brand recognition, ingredients, or front-of-package labels. The sequence in which these anonymized products were presented was counterbalanced to minimize the impact of order effects. Participants completed the **UND** and **NUM** tasks for each product in a set sequence. They were then presented with two nutrition labels from the same product category (e.g., "chips") for the **COM** task. After completing these tasks, participants completed the brief semi-structured interview.

*4.4.1 Procedures.* The experiment could be completed remotely via Zoom or in person at a local library. Prior to the study, participants completed a consent form, provided demographic information (Table 1), and contributed data on their typical nutritional behaviors and concerns (Figure 2). After the study commenced, participants were requested to verbally agree to abstain from using cell phones, calculators, or any other aids for questions involving calculations. For those in Group B, the experiment began with a tutorial to familiarize them with the features of the interactive nutrition label. All participants performed the **UND** and **NUM** tasks by filling out a Google Form on a web page next to their assigned label. After completing tasks for all three products, participants were redirected to a separate webpage. This page displayed two nutrition labels alongside a Google Form designated for the **COM** task.

After completing the tasks, a post-experimental interview was given to gather qualitative data on participants' experiences and attitudes toward traditional and interactive nutrition labels. Questions focused on the perceived utility and usability of the label they were assigned. Their purpose was to provide deeper understanding and context regarding how participants engaged with and understood the presented nutritional information.

*4.4.2 Analysis.* To assess the impact of different label types on nutrition label comprehension, we performed statistical analyses employing either the Student's t-test or the Mann-Whitney U test. The statistical test selection was informed by the distribution and variance characteristics of the data, enabling us to ascertain significant performance differences between Group A and Group B.

Alongside quantitative metrics, we conducted a detailed thematic analysis to examine data from the semi-structured interviews and think-aloud sessions with participants. The process began with an immersive reading of all transcripts, followed by open coding, where one researcher created initial themes based on emerging patterns and ideas in the text. These themes were continuously refined and grouped into broader themes that captured the core experiences and perspectives of the participants. The iterative nature of this process involved revisiting the data several times for accuracy and depth. Final themes were developed and validated through discussions within the research team.

# 5 RESULTS

Our results compare the performance of participants exposed to static labels (Group A) with those who interacted with interactive labels (Group B). We begin by presenting the quantitative findings from our study, followed by an examination of the qualitative results.

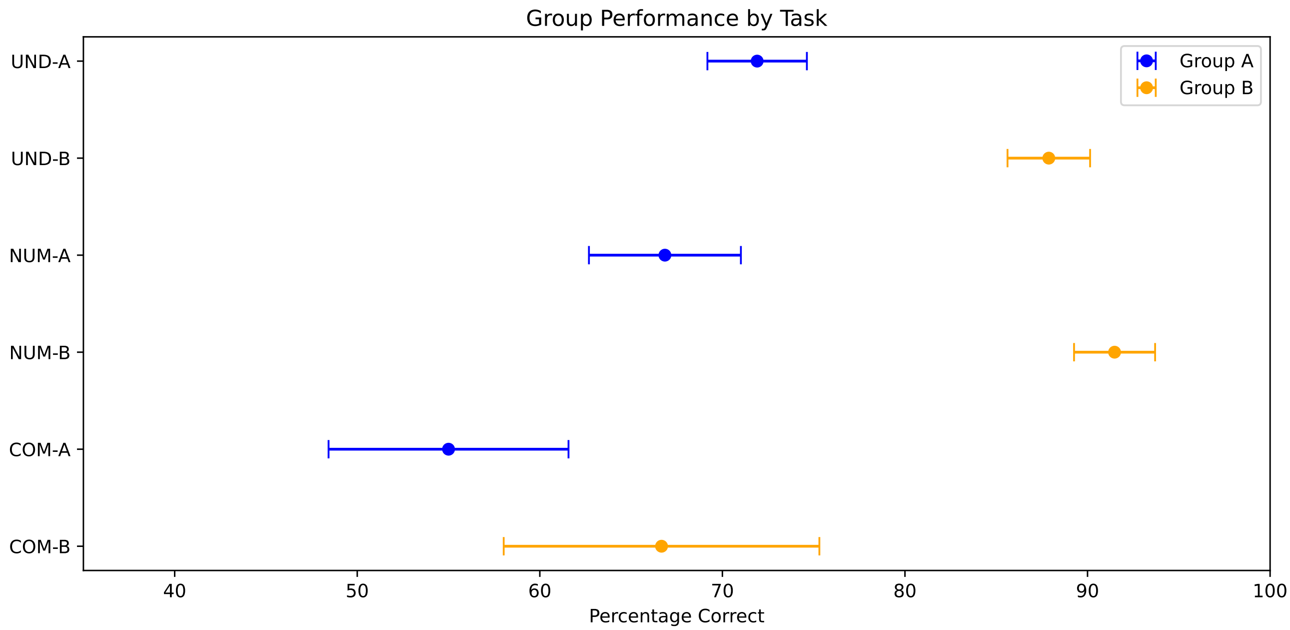


**Figure 3: Accuracy Across Task Types by Group: Group A, represented by blue bars, used static labels; Group B, represented by orange bars, used interactive labels. The tasks include Understanding (UND), Numeracy (NUM), and Comprehension (COM).**

## 5.1 Quantitative Results

*5.1.1 Understanding Nutrient Amounts (UND).* In evaluating the accuracy of participants' assessments of nutrient amounts, Figure 3 illustrates their performance. Given that the Shapiro-Wilk test for normality and Levene's test for homogeneity of variances indicated that parametric test assumptions were not met, we employed the Mann-Whitney U test for group comparisons. Our findings revealed that participants using the interactive nutritional label had significantly higher accuracy (U=292, $p < 0.01$) than those using static labels. Specifically, participants in Group A had an average accuracy of *M=71.9%, SD=16.3*, while those in Group B achieved *M=87.9%, SD=13.6*.

*5.1.2 Nutrition Numeracy (NUM).* In the **NUM** task, we assessed participants' ability to perform mathematical calculations based on a nutrition label. A correct response was considered if it fell within a ±2 serving range of the correct answer. Our data did not meet the criteria for parametric statistical tests; thus, we used the Mann-Whitney U test for comparison. As illustrated in Figure 3, we found that participants who were exposed to interactive nutritional labels exhibited a significantly higher level of accuracy (U=273, $p < 0.01$) in numerical calculations (U=273, $p < 0.01$) relative to those who interacted with static labels. To provide further detail, participants in Group A achieved an average accuracy rate of *M=66.9%, SD=25.0*, while those in Group B demonstrated a significantly higher average accuracy rate of *M=91.5%, SD=13.3*.

*5.1.3 Comparing Products (COM).* In the **COM** task, we evaluated participants' ability to compare nutritional information between two products. With binary multiple-choice questions, each question offered a 50% probability of being answered correctly. Unlike previous tasks, the data here met the criteria for parametric statistical tests, as confirmed by the Shapiro-Wilk and Levene's tests. Therefore, we used a Student's t-test to compare the groups. Contrary to the previous tasks, we found no statistically significant differences in accuracy between the groups (t=-1.07, p = 0.29). Specifically, the average accuracy rate for participants using interactive labels was *M=66.7%, SD=30.0* whereas those who interacted with static labels achieved an average accuracy rate of *M=55.0%, SD=22.8*.

## 5.2 Qualitative Results

This section presents the themes we identified from our thematic analysis of semi-structured interviews and think-aloud studies. Participants were assigned odd numbers (e.g., P1, P3) if they used a static label (Group A) and assigned even numbers (e.g., P2, P4) if they utilized the interactive label (Group B).

We begin our qualitative results by discussing the limitations of static labels, focusing on the challenges reported by participants in Group A. Following this, we highlight the advantages of interactive labels, detailing the positive feedback from Group B. The analysis then shifts to a closer examination of the specific interactive features, exploring their impact on Group B's comprehension and interaction. Finally, we present additional themes that emerged from the participant responses, such as the real-world applicability of interactive labels, a desire for personalization and a learning curve associated with using interactive features. Our primary goal throughout is to provide clear insights into how each type of label affects user understanding and engagement, directly addressing our research questions.

*5.2.1 Group A: Limitations of Standard Labels.* Participants assigned to Group A, interacting with static nutrition labels, frequently encountered challenges interpreting the information presented to complete the tasks. This difficulty was evident in understanding the numerical values and grasping the implications of these values for dietary choices.

A common issue among participants was a lack of understanding regarding the recommended daily nutrient intake. P19's confusion exemplified this, *"[after looking at the footnote] Well, what's the recommended daily value for calcium? I just know that it's 2000 calories a day."* Similarly, P7's vague understanding of protein needs —*"As far as I know, protein is good for you, but I don't really know how much you're supposed to have"*— further underscores the ambiguity present in static labels, particularly when individuals lack specific knowledge about their nutritional needs.

Participants often misinterpreted whether a food product was high or low in a nutrient, as their assessments were based on relative comparisons rather than established guidelines. For example, P15's assessment, *"Total carbohydrate seems extremely high. 17%, given that it's breakfast, and I think people have heavier meals later for lunch. So, I'd say high,"* shows the reliance on personal judgment rather than understanding the FDA's benchmarks for high ($\geq$ 20%) or low ($\leq$ 5%) nutrient contents [20]. P5's comment further highlighted this issue, *"I would say this is pretty high. Because it's 9% and relative to the other numbers, it takes up a higher percentage. Same for total carbs because it has the third highest number here on the label, so a lot in there."* These examples demonstrate the static label's limitation in conveying what constitutes high or low nutrient content.

Additionally, participants grappled with interpreting the various metrics on the label, such as percentages versus grams. P1's confusion, *"We don't know exactly how much percentage we should consume, how many grams we should consume, so it's difficult,"* and P19's admission, *"It wasn't super easy. Like I still don't understand daily values, not going to lie to you,"* reflects this confusion. These observations align with prior research in nutrition science, which has consistently highlighted the complexities users face when interpreting quantitative information on nutrition labels [35, 37, 38, 57].

Moreover, this lack of clarity extended to comparing products; many participants used the label's one-serving information without considering the varying serving sizes and total servings per container, affecting the accuracy of their comparisons. P15's statement, *"If I really wanted to pick the best product, I think it can be hard to. Okay. The frame of reference is often different, like the certain size or,"* succinctly captures the overarching challenge: the difficulty in making an informed choice due to inconsistent frames of reference and a lack of understanding of nutritional metrics. P5's experience further illuminates this issue: *"As I was going through it because I didn't know that, you know, the serving per container is like different from the serving size itself where they compare basically the nutrition in like a certain serving size like I thought it was for the whole thing."* This quote highlights a common misconception among participants that the nutritional information on the label pertains to the entire container, rather than a specific serving size, leading to misinterpretation of the nutritional content.

*5.2.2 Group B: Advantages of Interactive Label.* The experiences of Group B with interactive labels offered a stark contrast to those of Group A, highlighting the role interactivity can play in enhancing comprehension and engagement in nutritional decision-making. Unlike Group A, participants in Group B experienced an enhanced ability to interpret and utilize nutritional information effectively to complete the tasks. This overall improvement was evident in how these participants engaged with the interactive labels, facilitating a deeper understanding and more accurate answers for the **NUM** and **UND** tasks.

Participants in Group B found the interactive labels to be more intuitive and informative, particularly in aiding their dietary planning. For instance, P4's remark about the calculator feature, *"By clicking the serving size, I was able to determine the right amount of servings of this product for me per day... It was very useful in that aspect,"* and P2's comments on the helpfulness of the features, *"Like I said, the color and this calculator, they help a lot,"* demonstrate the positive perception of the interactive features among the participants.

In addition, our participants demonstrated the effectiveness of interactive labels in facilitating swift decision-making about food products. P8's experience using the color-coded legend underscores this: *"I literally just used the legend and chips B had less percentage for the orange ones and higher percentages for the green ones."* Likewise, P12's comment, *"I just went through and looked at like the orange and the green ones. So if it had lower orange ones and higher green, then that means it was better,"* highlights how the visual encodings streamlined the process of discerning healthier options. Furthermore, P16's reliance on the legend, *"Seems high but according to the legend, it is medium so medium,"* exemplify how the interactive features supported participants' confidence in completing the tasks.

Group B's experiences underscore the benefits of interactive labels in enhancing a more confident and informed decision-making process regarding dietary choices.

*5.2.3 Color Encodings.* Participants in Group B recognized the immediate visual impact of color encodings on the interactive nutrition labels, appreciating how they highlighted crucial nutrients. P2 expressed this sentiment: *"For me, the feeling is I first noticed the color...and I like that you use the red to highlight those things that potentially can be dangerous."* This reaction was shared by others, like P10 and P12, who agreed that the colors effectively drew their attention to important nutritional information. P8 further observed the utility of these encodings, emphasizing, *"So you would want to reach your goal for the greens, which I feel are goals to reach, and the oranges are like, 'don't go over this.'"*

The color encodings also aided participants in completing the nutrition tasks. P16, for example, mentioned how the interactive legend contributed to their confidence in assessing nutrient amounts: *"I'm just going by the legend for these answers."* Similarly, P12 found the color coding helpful in ensuring certainty in their evaluations: *"Like this one has a color, so I was more sure that this was medium."* Additionally, P20 emphasized the efficiency of the color coding, noting, *"I was able to look through faster based off of the colors in* *this chart right here,"* which demonstrates how the visual cues facilitated quicker understanding and evaluation of the nutritional information.

Despite their usefulness, some participants faced misinterpretations of the color encodings. P18 pointed out the potential for misunderstanding: *"High is good when in reality, like this red high, it seems good, but it's actually bad."* This participant also suggested a more explicit representation of beneficial versus harmful nutrients. Additionally, P6 highlighted a common misunderstanding about the color codes due to nuances in the hues, saying, *"The green coloring is the nutrients to get more of, so I think I may have read that backward."* This confusion arose from nuances in the color hues, where different shades of green were not immediately recognized as representing varying levels of that nutrient.

Interestingly, when a participant from Group A was queried about what they wanted to change on static labels to support their comprehension, they mentioned color as being an insightful thing to add, P15 saying, *"I would think I would want something that like automatically helps. Like, make it red for certain things that I think are bad, like I'm controlling my sodium intake."*

*5.2.4 Calculator Feature.* The calculator feature, an integral part of the interactive labels, was generally well-received for its ability to customize serving sizes. P4 appreciated this functionality for its precision in dietary planning: *"Well, I mean. I like the calculator part of it because I can decide on how many servings it's going to get me the closest to 100%."*

Participants utilized this feature in diverse ways, demonstrating its flexibility. P2, for instance, used it to adjust servings according to personal consumption needs: *"13 serving per container. I will probably just consume one or two. [changes the 'amount per serving' to 2],"* while P8 applied it to compare the entire container of different products: *"I'm gonna do per container. [adjusts the 'amount per serving' to reflect the amount of total servings in each container] And go chips B."* P10 further emphasized the feature's helpfulness in visualizing nutritional changes: *"See the change, see how the calculations for me. So I thought that was extremely helpful."*

While appreciated by Group B for the calculator's ease of use, we also heard instances where this could have served as a valuable tool for Group A, particularly in addressing mathematical challenges. Participants in Group A, who interacted with standard labels, faced difficulties with calculations related to the nutritional content. P3 acknowledged the complexity of some mathematical tasks: *"It was pretty easy to understand it. I think. Some of the math questions were hard. Doing the multiplication itself."* Similarly, P7 reflected on the challenges of computing servings required to meet daily nutrient values: *"This is how many servings of product are required to meet the recommended daily value. For vitamin D. How many? Let's say 2000. I have no idea. And now I could have calculated better, but..."*

*5.2.5 Details-on-Demand.* The details-on-demand feature in the interactive label was generally well-received by participants for its ability to provide additional information when needed. P20 expressed appreciation for this feature, noting its utility in reminding users of daily nutritional goals: *"I look at the nutrition label often, but having this information over here [pointing to the details-on-demand] is a great reminder of what you need to achieve in a day to be healthy."* Similarly, P8 found the feature helpful for those seeking more information: *"I feel like if I ever did want to know any more information, these boxes definitely do help out."*

Participants also acknowledged the role of the feature in reinforcing their existing knowledge and providing clarity where needed. P10 and P12 commented on its usefulness in offering information on demand: *"Hovering over, I used a little bit, probably not as much, but it was nice to have the information there,"* and *"In the hover overs like I didn't really read... I kind of already know what these are. So, like, hovering over it just like reaffirms that, I guess."*

Participants suggested that the details-on-demand feature could be improved by including more direct and personalized information to meet individual needs better. For instance, P2 suggested adding a scoring system to clarify whether nutrients in a product are considered 'good' or 'bad.' At the same time, P6 proposed including body-type-specific information, such as how a product could contribute to a diet based on gender, age, or weight.

However, for Group A, it was clear that the details-on-demand function could have been beneficial. P11 and P19's remarks about the need for more information on daily values and nutrient effects underscore the potential value of this feature for those less familiar with nutritional data, *"I'm not too sure of like what they all do. And how they're like. If they're good or bad to take, you know,"* and *"More information about daily values. Yeah,"* follows how participants in Group A would have appreciated the additional information that the details-on-demand could provide.

*5.2.6 Real World Application.* Our participants provided valuable insights on how interactive nutrition labels could be applied in real-world settings and their potential impact on consumer behavior.

As for the impact on consumer behavior, P4 highlighted the importance of being aware of specific nutritional content in influencing what consumers choose to buy: *"As for nutrition and all that, I mean it could play a factor...if an individual knows he's going to get too much sugar or something like that, it could play a big role in determining what the individual is going to purchase and what they're not going to purchase."* Complementing this perspective, P12 sheds light on the powerful impact of color as a visual encoding in altering shopping habits. The distinct visibility of particular colors on the interactive nutrition label, particularly the orange color indicating high nutrient levels, was described as striking and influential: *"Uh, just because I don't like seeing the orange number. It, like, really makes you notice it a lot more. So I think this would probably change my habits at least a little bit."*

Users' familiarity with nutrition information may influence their engagement with interactive label features. For instance, P2's revelation, *"I just realized that I didn't read any of the instruction at all... I already have some basic [knowledge],"* underscores how prior knowledge in nutrition can dictate the use of interactive labels. Individuals who already understand nutritional content can rely on their pre-existing knowledge. However, this familiarity does not lessen the value of additional information. Even for those with prior knowledge, supplementary details like hover-over features can reinforce their understanding.

Several participants reflected on the practicality of using interactive labels in their lives. P8 highlighted the challenges of adopting technology-heavy solutions like app-based labels, emphasizing the need for simplicity: *"But if it were to be like used on like an app,* *that would have to download it and go out of my way, I don't think I would go through the hassle of doing all that just to get these features."* Furthermore, P6 would have preferred quick and effortless interactions, especially during grocery shopping: *"No extra step like I'm going to the store like it's gotta be quick... I'm not necessarily going to be like, 'OK, well, let me check this interactive experience first."'*

*5.2.7 Desire For Personalization.* A clear demand emerged for personalized nutritional information in exploring user preferences for nutrition labels. P5, dealing with a vitamin C deficiency, expressed frustration with standard labels, noting the need for more specific information relevant to individual health needs: *"I struggle with vitamin C deficiency... why specifically vitamin D on the label? They could have vitamin C, they could have all these different vitamins."* This feedback highlights users' desire for labels tailored to personal dietary requirements. A few participants emphasized the potential benefits of such tailored nutrition labels. They envisioned nutrition labels that are not generic but cater to individual profiles, taking into account unique body types and dietary requirements. P6 expressed a desire for labels that provide personalized insights, envisioning a label that directly informs the user, saying, *"Oh, this is your body type, and this is what's good for that."* Additionally, P18's reflection on the legend's guidance, *"I would say this is low for me but it's medium according to the legend so I'll say medium,"* underscore the importance of offering more personalized interpretations of nutritional data. This highlights the need for nutrition labels that accommodate individual dietary goals and constraints, rather than solely adhering to general FDA guidelines.

Moreover, even participants less concerned with nutrition acknowledged the value of personalization for others. Despite their own disinterest in detailed nutrition information, P8 recognized how customized features could be especially beneficial for people with specific dietary needs or medical conditions, stating: *"Because I'm not an individual who generally cares, but I could see how if someone was required by a doctor or had some nutritional dietary issues, this would be really beneficial for that individual."*

*5.2.8 Learning Curve.* Despite conducting a tutorial, we observed that participants still encountered difficulties with certain functionalities, highlighting a learning curve in using interactive label features, particularly for our older participants.

A notable challenge encountered by participants involved the flexibility in serving sizes and the utilization of the feature for adjusting these sizes. P10 desired the ability to access half servings, stating, *"It'd be nice if you can maybe get to a half of serving, but that wasn't available."* This feedback highlights a missed opportunity in usability, as the functionality for inputting decimal servings(e.g., 0.5), though present, was not intuitively understood or used. Instead, participants often resorted to using the arrow keys rather than directly inputting amounts into the text box. Similarly, P6 initially overlooked the feature for changing servings, commenting, *"It's pretty easy to understand how many calories are involved, but I think it was easier once I realized I could change the servings here."*

Additionally, P4 chose to do the math aloud rather than use the calculator function while assessing the product. When queried, they admitted to having forgotten about this capability. While ultimately beneficial, this feature was only immediately apparent to some users, leading to some participants requiring additional guidance through the tutorial to grasp its functionality fully. However, once participants comprehended how the features worked, they could quickly complete the tasks that required calculations, streamlining their assessment of nutritional information.

Participants also needed help accessing daily nutritional guides and understanding the specifics of nutrient content. P10 highlighted the need for more explicit guidance on daily nutritional intake, stating, *"It might have been helpful to have a guide, you know, as to how much, you know, on a daily basis."* While the details-on-demand feature was designed to provide such information, its usage was less intuitive than expected. A few participants inadvertently discovered or failed to use this feature. P6 preferred more direct indications of nutritional value, stating: *"I think maybe just specifying. Literally like this is good for you. This is bad for you."* However, they did not utilize this feature to offer additional insights into which nutrients are beneficial or detrimental. This disconnect between the feature's potential benefits and its actual usage highlights the need for more prominent instructions and an intuitive design to enhance user engagement with these informative elements.

# 6 DISCUSSION

In our mixed-methods study, we observed varies results across three specific tasks: understanding nutrient amounts **(UND)**, nutrition numeracy **(NUM)**, and product comparison **(COM)**. Participants exposed to interactive nutrition labels showed significantly higher accuracy in the **UND** and **NUM** tasks than those who encountered static labels. However, no statistically significant differences in accuracy were noted between the groups in the **COM** task. This suggests that the efficacy of an interactive label may vary depending on the context and may not uniformly enhance all facets of nutrition literacy. Based on these findings, we have formulated design considerations that can guide HCI and design researchers in developing interactive labels that bolster nutrition literacy. We have also pinpointed specific avenues for future enhancement. Following this, we have included how researchers can utilize personalization in interactive nutrition labels and discuss potential real-world applications of digital labels.

## 6.1 Design Considerations

**Incorporating Flexible Computation Features:** Our results indicate the significance of interactive features, like the serving size calculator, in enhancing participants' ability to perform mathematical calculations, as evidenced in the **NUM** task. Given the significant role of numeracy skills in nutrition literacy [15, 57], it's crucial to design tools that accommodate users with a range of numeracy abilities, ensuring equitable access to insights from nutrition labels. The current tool focuses on modifying nutrient values based on serving sizes. To broaden its applicability and utility, we recommend integrating versatile functionalities that support various nutrition label variables. For instance, enabling users to input their desired daily nutrient values could prompt the tool to automatically suggest appropriate serving sizes. Such adaptive features would not only cater to diverse user needs but also facilitate more informed and efficient decision-making in nutrition management.

**Optimizing Intuitive Visual Encoding for Nutrition Interpretation:** Our research highlights the critical impact of intuitive visual encodings on aiding users in making swift and informed decisions when interpreting nutrition labels. We observed a pronounced preference among participants for color variations over shape distinctions in identifying nutrient levels as low, medium, or high. While our study focused on color and shape encodings for *nutrients of public health concern* [46], the complex nature of nutrition labels, encompassing various data types, calls for an expanded exploration of visual encoding techniques. Front-of-package labels, widely used by consumers in stores for product evaluation [26, 66, 69], could also be leveraged in the digital environment and present an excellent opportunity for exploration. Yet, the noticeable gap in consumer understanding of front-of-package labels [34] underscores the necessity for more straightforward and less cluttered presentation formats. Integrating interactive features such as a details-on-demand into digital front-of-package labels could substantially enhance their usefulness, particularly in clarifying content that users find confusing or ambiguous. Building on existing literature [13, 17, 41, 55], future research should investigate the effectiveness of various encoding methods in enhancing nutrition comprehension, especially for users with varying levels of nutrition literacy. We advocate for the development of universally intuitive visual encodings that are simple yet informative, possibly supplemented by customizable features that allow users to tailor the information display to their specific needs and preferences. Additionally, incorporating a comprehensive legend or guide alongside these encodings can significantly improve accessibility and ease of interpretation, ensuring that nutrition information is clear and actionable for all users.

**Implementation of Hover-Over Informational Features:** Our findings, corroborated by existing literature on nutrition education [23], highlight the challenge of accommodating diverse nutrition literacy levels among users. Notably, while participants well-versed in interpreting nutrition labels were less inclined to use on-demand details, they acknowledged its immense value for those less adept with interpreting nutrition labels. This disparity was further evident among participants using static labels (Group A), who frequently expressed uncertainty regarding the quantitative benchmarks for daily nutrient intake. Our findings suggest that hover-over informational features providing contextual information on-demand, can bridge this knowledge gap effectively. These features can help mitigate the visual clutter often associated with densely populated nutrition labels. We recommend incorporating such hover-over elements, designed to be adaptable and user-responsive, as a versatile solution for accommodating varying levels of nutrition literacy. Such features should not only be informative but also customizable, allowing users to tailor the information depth according to their individual needs and understanding.

**Facilitating Universal Usability Across Demographics:** Ensuring accessibility and ease of navigation for interactive features across a diverse demographic spectrum, especially in age and technological proficiency, is a well-known challenge in designing interactive technologies [31]. While the significance of user-centered and universal design is already recognized in our field, our study further reinforces this principle. We observed a notable variance in how quickly different age groups adapted to interactive label features. Although instructional tutorials are beneficial, they did not uniformly aid all users in our study, with some users either not fully utilizing the available features or forgetting their existence. Our findings reiterate the critical need for a design approach that is user-centered and universally accessible. In the context of nutrition labels intended for universal use, it is crucial that any added interactive features remain intuitive and do not introduce unnecessary complexity. Developing more intuitive and prominently displayed tutorial guides and incorporating interactive or multimedia elements could significantly enhance user understanding and engagement. Upholding this commitment to inclusivity ensures that nutrition labels' fundamental purpose—to inform everyone—is maintained and enhanced in digital environments.

**Enhanced Focus on Mechanisms for Product Comparisons:** Although the interactive features developed in our study were primarily intended to enhance individual product understanding, their potential in aiding product-to-product comparisons emerged as a significant aspect. Interestingly, our findings revealed that participants utilizing the interactive label did not show a significant improvement in performance for comparative tasks over those using the static label. This outcome underscores that enhancing individual product understanding through interactive labels does not directly translate to improved efficiency in comparing nutrition labels. This distinction aligns with findings from other researchers who categorize technology heuristics for nutrition interpretation and product comparison as separate entities [7]. It suggests a need for dedicated design elements specifically focused on facilitating effective comparison of nutrition labels. While visualization approaches have been explored to support users comparing products [13, 17, 55], their real-world applicability and effectiveness remain underexplored. Therefore, we recommend developing and empirically testing an integrated approach that distinctly addresses the visual, cognitive and interactive demands of comparing nutrition information, ensuring a more targeted experience in this aspect of label interaction.

## 6.2 Leveraging Personalization in Digital Nutrition Labels

Reflecting trends in interactive health technologies that focus on personalization [9], our findings reveal a strong user preference for nutrition labels tailored to individual needs. Instead of seeking generalized information, users are increasingly interested in labels that align with their specific health goals, dietary preferences, and lifestyle choices. This includes a demand for labels that provide general nutritional information and emphasize specific nutrients pertinent to personal health monitoring or family dietary requirements. Moving away from the one-size-fits-all approach of traditional static labels, the digital landscape offers vast potential for such personalization. Our results identify two key areas where personalization can revolutionize digital nutrition labels:

- **Customization for Individual Preference and Cognitive Processing:** Users expressed a strong desire for labels that can be tailored to highlight their nutritional priorities. This includes reordering nutrients to place personal priorities at the forefront and emphasizing specific nutrients that require closer monitoring. Such customization aids in quicker and more efficient decision-making, aligning the label more closely with individual health goals and dietary needs.

- **Demographic-Specific Nutritional Information:** The concept of 'daily value' on nutrition labels, generally based on a 2,000-calorie diet, serves as a standard guideline for an average adult's daily nutrient recommendations [19, 20]. However, daily values vary depending on various demographic factors such as age, weight, sex, health conditions (e.g., pregnancy), and activity levels [47]. Tailoring nutrition information to these individual characteristics can provide more accurate insights into how different food products affect specific dietary requirements. This personalized approach aligns better with individual nutritional needs and supports more informed and relevant dietary choices.

Beyond these customizations, there is a substantial opportunity to integrate dynamic personalization features into interactive nutrition labels. These could include real-time recommendations showing how a product aligns with an individual's daily nutritional needs or overall health objectives. By embracing these personalization settings, digital nutrition labels can transform into a versatile tool catering to a wide range of user needs. Personalization may include providing body-type specific information [4], offering goal-oriented dietary guidance [52], or even adapting suggestions based on lifestyle preferences [53]. These advancements enhance the practicality of nutrition labels and contribute to a more personalized and engaging approach to health and nutrition management.

### 6.3 Digital Platforms for Interactive Label Implementation

Our study revealed a gap in user perception regarding the real-world applicability of interactive nutrition labels. Participants recognized the benefits of interactive features but raised concerns about their practicality in everyday contexts such as grocery shopping. These concerns mirror the broader challenges in health technology adoption [22]. However, the evolving digital landscape offers promising solutions, especially in online grocery shopping and augmented reality.

The COVID-19 pandemic has significantly accelerated the trend of online grocery shopping [27, 54]. In addition, there has been an increase in the use of digital platforms for meal planning and culinary skills enhancement [11, 12]. These platforms, already equipped with static nutrition labels, are ideally positioned for the transition to more dynamic, interactive labels.

Moreover, augmented reality (AR) mobile assistants, known for aiding healthier choices in-store [2, 16, 30], offer an avenue for further integrating interactive labels. This technology can transform the shopping experience into an interactive, informative journey, allowing users to access in-depth product information in an engaging, immersive manner. Beyond shopping, AR and interactive labels have vast potential in broader dietary management – from meal planning and recipe nutrition calculation to making informed decisions about pantry items and ensuring alignment with health goals. The visual and interactive nature of AR is particularly effective in illustrating how different foods contribute to an individual's nutritional objectives, thereby enhancing meal planning and overall diet management.

Our research lays the groundwork for understanding the efficacy of interactive features in nutrition labels. Future studies should delve deeper into the real-world application of these labels in various scenarios – addressing concerns like allergen information, product diversity, budget limitations, and brand influence. Integrating interactive labels into everyday digital tools and activities can make nutritional information more accessible and relevant, supporting essential tasks like dietary planning, grocery shopping, and meal preparation. The objective is to transition from viewing interactive labels as a novel concept to making them a fundamental component of a comprehensive digital health and nutrition ecosystem.

## 7 LIMITATIONS AND FUTURE WORK

While our study offers valuable insights into the potential benefits of interactive nutrition labels, it is important to acknowledge several limitations. First, the sample size of our study was relatively small, with only 24 participants. This limits the generalizability of our findings and may not adequately capture the diversity of experiences and preferences among a broader population. Second, our study focused on implementing only three new features for interactive labels designed to support numeracy in understanding food labels. However, nutrition literacy is a multi-faceted concept, and our labels may not support all the skills required to understand and utilize nutritional information. Third, the color encodings used in our interactive label followed the traffic-light nutrition labeling system, which uses red and green colors. While this is a commonly used in nutrition science, it poses accessibility issues for individuals who are colorblind. Although we did not exclude participants who were colorblind, this remains a limitation that could affect the applicability and inclusivity of our interactive labels. Moreover, other accessibility concerns, such as low vision, motor skills impairments, and various disabilities, were not explicitly considered in our study. This oversight potentially restricts the accessibility of our interactive labels for a wider range of users with differing abilities.

Furthermore, the need to consider external factors and user-specific elements, such as individual dietary habits, allergies, and cultural influences on food choices is critical in the application of interactive nutrition labels. These factors could significantly influence how consumers interact with and interpret nutritional information. Additionally, we did not evaluate the practicality and utility of interactive nutrition labels in real-world scenarios, an aspect critical for understanding its broader applicability and utility. Finally, the limitation in the variety of food products selected for this study may not adequately represent the diverse range of products encountered in typical grocery settings.

Our study opens several avenues for future research in interactive nutrition labels. One primary area for further exploration involves expanding the range of interactive features to support additional aspects of nutrition education, such as interpreting ingredients and emphasizing specific dietary needs. Considering that nutrition literacy spans a wide range of skills and knowledge—from grasping nutrient content to making informed food choices—additional interactive features could prove beneficial in supporting other tasks as well. Future research should concentrate on the development and evaluation of innovative features and visual representations, aiming to provide a comprehensive strategy for leveraging interactivity to enhance consumer understanding of nutritional information.

To address a key limitation identified in our study, future work should concentrate on enhancing interactive label designs for product comparisons. We found that while certain design elements were effective for evaluating individual products, they did not necessarily translate into equal effectiveness for comparing multiple products. Considering the frequent need of consumers to compare products, particularly in a shopping context, this area presents a significant opportunity for improvement in interactive label design, aiming to simplify and improve the accuracy of product comparisons.

## 8 CONCLUSION

As health technology advances, interactive nutrition labeling offers a wealth of opportunities, particularly with the growing trend of online grocery shopping and the pressing need for improved nutrition education. This digital era has unlocked new avenues for enhancing consumer understanding of nutritional information, moving beyond the constraints of static labels traditionally affixed to product packaging. The primary objective of our study was to examine the efficacy of various interactive features incorporated within nutrition labels in enhancing performance on nutrition label tasks.

Our research demonstrates that integrating interactive elements, such as calculators, visual encodings, and hover-over informational details, can elevate user understanding of nutritional information. These enhancements were corroborated by both qualitative and quantitative data, revealing increased improvements in task performance and eliciting favorable user feedback. Additionally, we contributed actionable design considerations for researchers utilizing technology to support nutrition label interpretation. This study not only underlines the transformative potential of interactive labeling mechanisms for nutrition education but also opens the door to further interdisciplinary research.

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## A DETAILED ANALYSIS OF PARTICIPANT GROUP BALANCE

We provide a comprehensive overview of the analysis conducted to demonstrate a balanced representation of participants in our study. The analysis aimed to compare the two groups across various demographics and nutrition behaviors, namely age, gender, race, education level, and self-reported nutrition behaviors. The primary goal of this analysis was to validate the effectiveness of our grouping strategy. By ensuring that the two groups were comparable in terms of key demographic and behavioral characteristics, we aimed to enhance the internal validity of our study and ensure that any observed effects could be attributed to the intervention rather than pre-existing group differences. We used the Mann-Whitney U test to compare our two independent groups based on a continuous variable, like age, and ordinal variables, such as self-reported nutrition behaviors—shown in Table 2.

| Variable | Statistic | p-value |
|---|---|---|
| Age | U = 50.5 | 0.225 |
| Confidence | U = 76.0 | 0.825 |
| Importance | U = 63.5 | 0.636 |
| Frequency | U = 72.0 | 1.0 |

**Table 2: Numerical data analysis results**

For categorical variables like gender, race, and education level, we utilized Chi-square tests, as shown in Table 3. This choice was driven by the nature of these variables and the need to understand if the distribution of these categories differed significantly between the two groups.

| Variable | Chi-square Statistic | p-value |
|---|---|---|
| Gender | 1.688 | 0.194 |
| Race | 7.311 | 0.397 |
| Education | 5.867 | 0.319 |

**Table 3: Categorical data analysis results**

Our analysis revealed no significant differences between the groups across all examined variables, confirming the efficacy of our approach in achieving a balanced representation. This finding is crucial for the internal validity of our study, as it suggests that any observed differences in study outcomes can be attributed with greater confidence to the effects of the intervention rather than to pre-existing differences between groups.

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