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Grappling with Online Grocery Shopping: An Age-Related study

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ABSTRACT

In both an increasingly digital and aging society, natural age-related cognitive changes take place, which may negatively affect performance when using increasingly complex digital interfaces. Obtaining daily needs such as groceries becomes more difficult with age and shopping for groceries online presents a challenge to many older adults. The purpose of this study is to understand how and in what ways age affects online grocery shopping performance. 32 participants were recruited for this study consisting of 17 younger adults and 15 older adults. Participants were presented with sets of tasks which required them to mentally calculate the quantity of food they can purchase within a given budget. Eye tracking and survey methods were used during the study. Our results show that age negatively impacts cognitive load. Cognitive load was found to negatively impact performance in online grocery shopping tasks. Self-efficacy showed to have a mild moderating effect on said relationship.

Keywords

Online grocery shopping, aging, user experience, cognitive load, self-efficacy, arithmetic complexity

INTRODUCTION

The population of adults 60 years and older is projected to increase nearly twofold between the years 2015 and 2050 and life expectancy is on the rise in Canada, a trend seen in many countries worldwide (Public Health Agency of Canada, 2021). Additionally, older adults are surpassing the growth of children and younger adults. Concurrently, the world is becoming increasingly digital and online shopping has become increasingly common, particularly since the COVID19 pandemic (Lebow, 2021). When aging, normal cognitive changes occur, making it more difficult and time consuming to process and retain novel information (Rozencwajg et al., 2010). As a result, aging leads to an easier overload of cognitive effort when being faced with new tasks or learning experiences (Granholm et al., 1996). Older adults are less likely to have been exposed to technologies compared to young adults, are less likely to have shopped online, though this trend is decreasing since the global pandemic (Lebow, 2021). It has been found that individuals, including older adults, who shopped for online groceries during the pandemic are more inclined to continue this trend at a later. Additionally, older adults face many other obstacles in obtaining their daily goods, namely difficulty with mobility and transportation. Older adults who use online grocery shopping for the first time, compared to their younger counterparts, also take nearly twice as long to complete their orders (Sjölinder, Hook & Nilsson, 2000) and require several attempts before feeling at ease with the task (Haire & Miller, 2020).

Online grocery shopping is not only made more difficult to older adults due to their natural propensity to increases in cognitive load, combined with the lesser use of online grocery shopping platforms than younger adults. There are also additional challenges of online grocery shopping due to its arithmetic complexity (Desrochers et al., 2019). Online grocery shopping involves multiple mental calculations, including calculating cost per weight, estimations and conversions, among others. Despite the challenges older adults face while using online shopping platforms, this population group seems seldom consulted when designing these platforms (Haire & Miller, 2020). Their different design needs are not necessarily met, despite the need for facilitated access to essential goods such as groceries. Due to their lack of exposure to technologies compared to younger adults, older adults' digital self-efficacy is also lower on average (Czaja et al., 2006) and this is also true for online grocery shopping. There is a significant lack of literature honing in on aging and online grocery shopping performance and very little in way of tackling arithmetic complexity in this context. As such, we wish to further research on older users' experience in online grocery shopping with a particular focus on the numerical information which is so present in this type of shopping, as online grocery shopping is on the rise for this population group. In order to further explore the topic, we propose the following research question:

RQ: How and under what conditions does age affect online grocery shopping performance?

Before continuing, we wish to explain the structure of the article. Firstly, we will begin by introducing the literature review and theoretical foundations leading to the hypotheses proposed. Then, we will present the study's methodology, including the overview of recruitment and participants, the experimental design, the experimental task and stimuli, the procedure and materials, as well as the presentation of the research variables and explanation of the data analysis. Next, the results and discussion will be presented. Finally, we will end the article with the limitations and future directions.

LITERATURE REVIEW

Age and Cognitive Load

Interacting with an overly complex task overworks a person's cognitive assets (Sweller, 1988) but a modestly challenging task allows one's cognitive resources to be optimally used in order to effectively solve the problem at hand (Chandler & Sweller, 1991). Sweller's Cognitive load theory posits that when the cognitive effort is too great, task performance decreases. This is due to the limited temporary storage capacity of one's working memory (Sweller, 1988). Younger individuals are more likely to process and absorb new information more rapidly and readily (Van Gerven et al., 2002). Inversely, due to natural cognitive changes, older adults' cognitive capacity is more easily exceeded when faced with novel tasks (Van Gerven et al., 2002). However, the way information is presented can influence task performance by either increasing or decreasing cognitive load (Van Gerven et al., 2002).

Arithmetic Complexity

Arithmetic complexity is defined by how challenging any given calculation is (Campbell, 2005). Understandably, a simple 1 digit by 1 digit multiplication like 1 x 2 = 2 is viewed as easier than a 2 by 2 digit multiplication, such as 56 x 71 = 3976 since there is more mental processing involved (Campbell, 2005). As children, we are first taught simple arithmetic by means of numbers and counting and we learn increasingly complex strategies in order to solve more elaborate mathematical problems. For instance, after a child achieved proficiency calculating with integers, the introduction of decimals can take place. However, in the natural aging process, one's cognitive abilities gradually begin to decline, as does arithmetic capacity as compared to younger adults (Avcil & Artemenko, 2023). Interestingly, when faced with simple arithmetic tasks, younger and older adults tend to perform similarly (Lemaire & Arnaud, 2008). It is only when more complex problem-solving strategies must be employed, in the context of more complex arithmetic tasks that younger adults tend to outperform their older counterparts (Lemaire & Arnaud, 2008).

Age and Online Grocery Shopping

Aside from the differences between shopping for groceries in person and online, online grocery shopping behavior is different for older adults (Lesakova, 2016). As previously mentioned, older adults have less experience shopping online than younger adults do and this includes online grocery shopping (Bezirgani & Lachapelle, 2021). It takes them longer to choose grocery items (Lesakova, 2016) and they have a more negative view of shopping online, which is aggravated by their lack of experience with online shopping, including groceries (Bezirgani & Lachapelle, 2021).

Online grocery shopping is more challenging than many other types of online shopping. In online grocery shopping, the user must consider the way product price information is presented (weighed or individual), different coupons or discounts (ex., 2 for 5 from select products), multiple brands providing similar products (for example, smoked almonds from different brands, which differ in price and quantity), among other variables. A recipe may require a specific amount of an ingredient and the consumer must know how much of this ingredient they might have at home and mentally approximate the amount needed to purchase (Desrochers et al., 2019). These factors, among others, contribute to the arithmetic complexity of online grocery shopping (Desrochers et al., 2019). Regrettably, little literature appears to exist on the topic, particularly when combining aging, online grocery shopping and arithmetic complexity (Bezirgani & Lachapelle, 2021).

Age and Digital Task Performance

Digital task performance can be understood as how much users are capable of reaching set digital task performance goals (Burton-Jones and Straub, 2006). While aging is known to impact digital task performance, there is a scarcity of literature concentrating on natural age-related changes on technology use (Tams, 2022). It is generally agreed upon that older adults are less inclined to perform efficiently on novel digital tasks compared to younger adults. This is due to the natural cognitive changes impacting the ability to store and manipulate novel information required to solve digital tasks (Zeithalm & Fuerst, 1983). Moreover, performance goals in online grocery shopping differ for younger adults compared to older adults. Younger adults are more likely to favor convenience and saving time since they often have young families. Older adults, on the other hand, have more free time on average but value saving money and receiving assistance to carry heavy items (Lesakova, 2016). Ultimately, what both younger and older adults wish for is a frictionless user experience when shopping for groceries, including online grocery shopping (Giroux-Huppé, Sénécal & Léger, 2019). As previously outlined, online grocery retailers already face hurdles in adequately conveying information to their customers due to the arithmetic complexity of shopping for groceries online when compared to other types of e-commerce (Desrochers et al., 2019). Unfortunately, it is older adults who are at a particular disadvantage when presented with challenging tasks involving arithmetic calculations (Rozencwajg et al., 2010).

Age and Digital Self-Efficacy

Self-efficacy is understood as the belief one has in their ability to attain a predefined performance goal, as well as their belief in their ability to carry out behaviors that make realization of these goals possible (Bandura, 1997). An individual with a lesser exposure to a stimulus, in this case technologies and digital experiences such as online shopping, is less likely to have an elevated self-efficacy. This is the case for older adults, as on average, their exposure to technologies is not equal to their younger peers (Czaja et al., 2006). Unfortunately, even when older adults understand how technologies can aid them with routine tasks such as paying their credit card bills or purchasing essential goods, they are less likely to believe in their ability to successfully complete these tasks digitally (Czaja et al., 2006). This fact is problematic since lower self-efficacy is often accompanied by a lower motivation or drive to mobilize efforts to complete a digital task (Tams, 2022). While there is a lack of literature with regards to online shopping self-efficacy, it is reasonable to understand that self-efficacy may play a role in influencing cognitive load and its subsequent impact on online shopping task performance.

Hypotheses

Considering the theoretical foundation and our research questions, the following research hypotheses are presented in this study:

H1: Age positively affects cognitive load.

H2: Arithmetic complexity moderates the relationship between age and cognitive load.

H3: Cognitive load negatively affects online grocery shopping performance.

H4: Self-efficacy moderates the relationship between cognitive load and online grocery shopping performance.

The following research model is brought forth to answer our research questions:

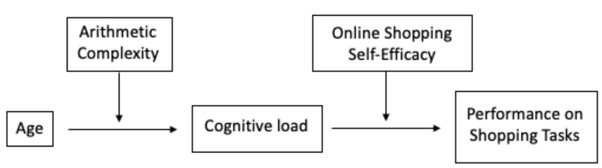

Figure 1. Research Model

METHODOLOGY

Participants

Both younger and older adults were recruited for this study in order to be able to compare results based on age brackets. Younger participants ranged between 18 to 35 years old and older adults were 60 years and over. 32 participants were recruited, 17 being younger adults ranging from 21 to 32 years ($\bar{x}$ = 26 years, σ = 4.50) and 15 being older adults ranging from 60 to 78 years ($\bar{x}$ = 66 years, σ = 6.43).

Multiple recruitment methods were employed. The means of obtaining participants include using the research panel of the university, advertising the study near the university via poster with a QR code. Older adult residences and activity center managers were also contacted, in order to allow for advertising at these locations with a poster. Snowball sampling was also employed. Participants had the option of participating at the HEC Montréal campus or in their homes in order to create a more inclusive environment for older adults, particularly those in their seventies and beyond.

Experimental Design

The study is a 2 (arithmetic complexity: price per product or price per weight) x 2 (arithmetic complexity: integers or decimals) within-subjects design. The lowest arithmetic complexity condition and the highest arithmetic complexity condition were retained, in order to reflect either extreme.

Experimental Task and Stimuli

To isolate relevant variables and to facilitate functioning of the eye tracker and its associated software, simple static stimuli were created with large text, minimal coloring and minimal visible branding.

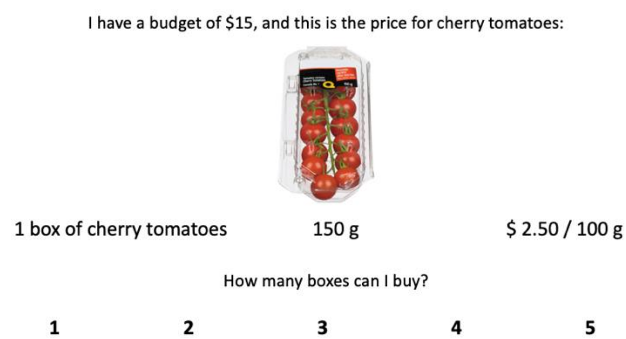

Figure 2. Example of a high arithmetic complexity stimulus

As shown in figure 3, each stimulus included the user's budget, an image of the purchased produce, the quantity of food (ex. 1 box of cherry tomatoes), the weight (ex.150 g) and the product price information (ex. $2.50 / 100g). Prices and weights were inspired from local online grocery retailers. Participants were asked to maximize the amount of produce they can purchase with their given budget. The answers always ranged from 1 to 5. All information was included on the stimulus even when not required to complete the task. For instance, when the produce was listed per product (ex. 1 orange, priced at 1$ per orange, the weight was still included). This emulated a more realistic experience, considering that in an actual online grocery shopping experience, product price information is displayed differently (ex. a prepackaged bag, in bulk, etc.)

Setup, Procedure and Materials

An IBM laptop set up with the Sensorimotor Motoric Instruments eye tracker (SMI Experiment Center version 3.0, Teltow, Germany) was the main testing interface. The moderator sat near the participant with an additional laptop that mirrored the participant's screen via TeamViewer version 15.31.5 and controlled the progression of the study's tasks. Since participants were allowed to participate in their home setting or in a reserved room at HEC Montréal, the moderator was able to prepare the portable computers and eye tracker prior to the participant's arrival. If not, the moderator set up the study while the participant was reading the consent form. Participants began by answering a pre-test questionnaire. Next, they were provided with an explanation of the grocery task and had a practice trial so they can understand and become familiar with the task at hand. This was also done to reduce the chance of a learning effect.

The grocery task involved a series of two conditions of four stimuli. Conditions were randomized for each participant. The participant was instructed to maximize the quantity of food based on each displayed budget. For example, in figure 3, they have a budget of $15 and were asked to calculate the maximum number of boxes of cherry tomatoes they can purchase with this budget. They were asked to answer out loud (the number of boxes from 1 to 5) as well as to look at the correct answer (gaze at the number from 1-5 in order for the eye tracker to capture their answer). After each condition, participants were instructed to complete a questionnaire. To create all questionnaires for this study, Qualtrics (Seattle, WA, USA) was used. Finally, the participant read and signed the compensation form and was renumerated $20 cash for their participation. The duration of the study of was approximately 60 to 90 minutes. This study was approved by the Ethics Review Board (ERB) at HEC Montréal (#2023-5016).

Measures and Research Variables

Pertinence of Implicit and Explicit Measures

Implicit measures, such as psychophysiological tools can provide rich insights. Explicit measures such as self-reported measurements obtained through questionnaires also aid in observation. While explicit measurements can supply insights on a user's thoughts, perceptions, and opinions, they do not account for the user's subconscious behaviors and reactions (de Guinea, Titah & Léger, 2014). Combining the two provides a complexity akin to the human experience.–Additionally, incorporating implicit measures reduces the likelihood of common method biases which may result from explicit measures (de Guinea, Titah & Léger, 2014).

Arithmetic Complexity

Arithmetic complexity is defined as the level of difficulty of a task involving a mathematical equation (Campbell, 2005). As such, the study manipulations created low and high arithmetic complexity conditions. In pre-tests, the performance score results proved significantly different for each condition. The low complexity condition resulted in notably higher performance scores, while the high complexity condition resulted in the opposite.

Cognitive Load

Cognitive load is defined as the level of working memory used during a task (Sweller, 1988). Put differently, it is the degree of mental effort exerted by a person when faced with a novel and demanding task (Chandler & Sweller, 1991). Cognitive load can be measured in its objective experience by means of the task-evoked pupillary response (TEPR) (Hess & Polt, 1964). When faced with a challenging task, it is normal for one's pupils to dilate, which serves as an implicit, physiological indicator of the mental effort associated with various cognitive processes, such as memory retrieval and problem-solving (Reilly et al., 2019). This analysis is known as pupillometry and is well-documented in the literature (Reilly et al., 2019). Notably, arithmetic tasks have been known to increase pupil dilation significantly (Piquado et al., 2010). Cognitive load was thus measured through pupil dilation in millimeters, obtained by the SMI eye tracker. In its subjective experience, cognitive load was measured by a validated 7-point Likert scale questionnaire by Pereira (2000).

Self-Efficacy

Self-efficacy is defined as "a person's belief in their ability to execute behaviors necessary for performance attainment" (Bandura, 1997). Given that this measure is stable and context-specific, this score was measured once. Since self-efficacy is subjective, a validated 1-7 Likert scale questionnaire was employed from Tams (2022).

Task Performance

Task performance is defined as the level which individuals can meet their performance-related goals (Burton-Jones and Straub, 2006). This variable was measured objectively by their task performance rank.—A participants' performance rank considered both the time and accuracy of the answer. To further explain, computing the rank compares each participants' objective performance score compared to the lowest performer in terms of time on task. A low rank designates a higher performance and vice versa. Subjectively, task performance was measured by a validated 7-point Likert questionnaire by Tsai, Chen & Liu (2007).

Data Collection, Extraction and Analysis

Out of the 32 participants, 10 were excluded from eye tracking analysis due to a loss of data, potentially due to the environmental effects such as lighting or poor calibrations. Since many older participants did wear glasses, calibrations were often more difficult. However, their other data was retained and analyzed. Eye tracking areas of interest (AOIs) were centered on the numerical information on the stimuli such as the one presented in Figure 3. These areas were selectively delimited prior to analysis. Therefore, the final analysis involved the budget, the product weight and the product price information. Eye tracking data was exported and extracted through SMI's software, SensoMotoric Instruments BeGaze. The data was compiled and parsed in Microsoft Excel version 16.66.1. The questionnaire data was extracted from Qualtrics. The datasheets were analyzed in SAS Studio (SAS Institute Inc., Cary, NC, USA). Descriptive statistics, paired t-tests, independent t-tests and repeated measures multivariate regressions-were used to analyze the results.

RESULTS

As previously discussed, multiple measurements were taken for the research variables. For example, cognitive load was measured both in its lived experience (objective eye tracking measurements) and in its perceived experience (self-reported cognitive load). The data with the strongest support is presented in Figure 4 and discussed in the results section. Multivariate repeated measures linear regressions were employed to analyze the hypothesis results. All analyses are one-tailed as directionality was assumed. Variables were analyzed and were subsequently determined to contain normality of distribution.

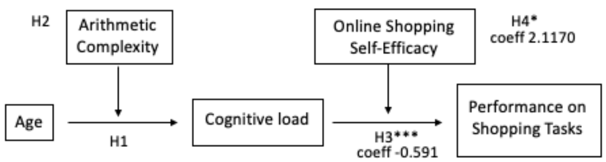

Figure 3. Research Model with hypothesis results

One star (*) designates a p value ≤ 0.1, two stars (**) designates a p-value ≤ 0.01 and three stars (***) designates a p-value ≤ 0.001

Age, Cognitive Load and Task Performance

Overall, age was found to have a strong negative effect on cognitive load (coefficient = -0.08; p = <0.0001/2) (H1 unsupported). Cognitive load was found to differ substantially among younger adults than older adults (p = 0.0001), with older adults having a significantly lower task-evoked pupil response (TEPR), an indicator of elevated levels of cognitive load (Reilly et al., 2019). Moreover, cognitive load was found to have a negative effect on online shopping task performance (H3 supported, coefficient = -0.056; p = <0.0001/2). Therefore, in the context of online grocery shopping, age negatively impacts cognitive load and cognitive load is a predictor of online grocery shopping task performance. The more elevated was the cognitive load, the lower the task performance scores were. Interestingly, task performance scores were oftentimes comparable in younger adults and older adults.

The influence of Arithmetic Complexity

While arithmetic complexity was not found to be a moderator between age and cognitive load (H2 unsupported, coefficient = 0.004; p = 0.2118), comparing the low arithmetic complexity and high arithmetic complexity conditions yielded interesting trends. In general, task performance was significantly worse in high complexity conditions. For example, the mean objective score for the high complexity task was 62.5% and the mean objective score for the low complexity task was 89.84%, p = 0.0001. Additionally, cognitive load measures were also significantly more elevated in the high complexity condition than in the low complexity condition. For example, participants scored their cognitive effort an average of 3.7/7 for the high complexity condition, as opposed to an average of 2.19/7 for the low complexity condition, p = 0.0002.

The influence of Self-efficacy

Self-efficacy was shown to have marginal effect as a moderator between cognitive load and online shopping task performance (H4 marginally supported, coefficient = 2.1170; p = 0.0912). However, descriptive statistics and t-tests show that younger adults have substantially higher self-efficacy scores ($\bar{x}$ = 6.059/7, σ = 0.689) than their older counterparts ($\bar{x}$ = 5.244/7, σ = 1.190). Consequently, this difference is statistically significant (p = 0.0121). In other words, self-efficacy has a more discrete effect on the relationship between cognitive load and online grocery shopping performance. However, there is some evidence that self-efficacy plays a role in moderating the relationship between cognitive load and task performance.

DISCUSSION

Interestingly, this study shows that the positive effect of age on cognitive load has not shown to be applicable in the context of online grocery shopping. The opposite phenomenon—that is, increased age has a direct positive effect on cognitive load-- has previously been observed in other contexts. Instead, there is support that older adults performed similarly to their younger peers. Our results also show that elevated amounts of cognitive load results in lower performance scores. This was found to be the case for both younger adults and older adults in the context of this study and is in accordance with Sweller's Cognitive Load Theory. The psychologist found that exhausting one's limited mental capacities led to an elevated cognitive load which in turn results in lower performance scores (Sweller, 1988). This study's performance goals focused on obtaining the best value for one's money in terms of quantity of food. This is relevant to many especially with rising costs of food. However, other individuals may not have such worries and may wish to find the best product quality instead. Ultimately, the trends seen in this particular context demonstrates that there is a complex interplay of variables affecting online grocery shopping. The multitudes of factors influencing our online grocery shopping including our purchasing power, quality of foods and shelf life all contribute to online grocery shopping to be among the more stressful types of shopping experiences (Freeman, 2009).

Next, it was noted that online grocery shopping is considered a more stressful experience and more challenging in terms of its arithmetic complexity. This complexity becomes evident when we observe how differently users perform in tasks involving more intricate mental calculations such as determining price per weight or working with decimals when compared to tasks with simpler mental calculations. This observation aligns with the findings of Desrochers et al. (2019), where users were instead asked to purchase ingredients for a recipe, requiring them to make precise calculations for missing quantities for their recipes and the food's associated cost. Curiously, arithmetic complexity did not moderate the relationship between age and cognitive load as expected. While the role of arithmetic complexity is less straightforward than anticipated, its impact on performance in particular would warrant further exploration.

Users demonstrated their ability to accurately predict both their cognitive load and their performance in the shopping tasks. Therefore, they perceive when a task is cognitively effortful, when their cognitive abilities feel strained and consistently answer that when this is the case, their performance is lower and vice versa. In a real-life context, this may align with user perceptions on a fluid user shopping experience, where the information is easily retrievable and quantities and costs of foods are simple to estimate. In addition, older adults exhibited lower self-efficacy in the context of online grocery shopping, which corresponds with existing literature on older adults' self-efficacy in using technologies (ex. Czaja et al, 2006). Our findings suggest that self-efficacy may play a small role in moderating the relationship between cognitive load and online grocery shopping performance. To recapitulate the research question, we wished to understand how and under what conditions age affects online grocery shopping performance. Interestingly, increased age led to decreased cognitive load. Its mechanisms include a strong and direct effect of cognitive load on task performance. However, the more elevated the cognitive load, the lower was the performance on shopping tasks and an elevated belief in one's ability (e.g. self-efficacy) does moderate performance scores.

As a whole, these results demonstrate that the way numerical information is presented on an online grocery shopping website influences their online shopping experience, particularly with regards to reaching their goals, such as saving money or purchasing accurate quantities of products. A poorly designed website may overwhelm users and make it more difficult to quickly predict the quantities of products and cost. Ultimately, these factors may lead to users receiving a different number of items than they had intended or seeing unexpected costs in their shopping carts. The findings of this study emphasize the importance of simplifying numerical information presentation whenever possible and minimizing mental calculations required from users. This can be achieved by providing clear visual cues, especially when dealing with bulk items. For instance, showing a small cup of scooped peanut butter in bulk packaging can help users visualize the quantity they are purchasing. Additionally, the introduction of estimators that allow users to input specific amounts (ex. grams of deli meats) to estimate their desired product quantity, can enhance users' mental models of their purchases and potentially reduce cognitive load.

Limitations

This study is not without its limitations. Firstly, cognitive effort was measured via participants' task-evoked pupillary response, or pupil dilation. However, pupils naturally dilate or constrict based on the ambient lighting as well as in reaction to complex tasks (Piquado, Isaacowitz & Wingfield, 2010). Since many of the older adults participated in their home environment, it was difficult to control for equal lighting among participants. In addition, there are also natural age-related biological changes which result in older adults being naturally more sensitive to stimuli which impacts pupillary dilation (Piquado, Isaacowitz & Wingfield, 2010). This may explain the unpredicted results with regards to aging's effect on cognitive load.

Second, testing in users' home environments provides an interesting opportunity to increase external validity. The external test environment however does decrease internal validity as a result. On account of this, additional testing in a more controlled environment would be relevant. Participants also used static elements replicating portions of an online grocery shopping experience, but did not interact with an actual online grocery shopping platform. While this was an intentional choice in order to facilitate eye tracking analysis, as well as to control for branding, colors and website layouts, among others. It would be pertinent to do further testing on online grocery shopping websites or applications. Lastly, in order to analyze the research model, the datasets needed to be condensed due to repeated measures, which impacts statistical power. In addition, a total of 32 participants is small if our aim is to generalize research results. Increasing sample sizes would remedy this problem.

CONCLUSION AND FUTURE DIRECTIONS

With individuals increasingly shopping online and online grocery shopping experiencing growth since the global pandemic, an increasing number of individuals rely on online grocery platforms to access food and other daily essentials. The purpose of this study was to understand how and in what ways aging affects online grocery shopping performance. In particular, a major focus was placed on the effects of conveying numerical information. In a time where we are increasingly using online shopping platforms, these venues warrant careful consideration and further analysis. Ultimately, the presentation of information on a website impact how the user performs on the website, regardless of age. However, there are particularities to the older adult shopping experience and given the aging population, it is helpful to conduct research to further understand the unique needs of older adults in the context of online grocery shopping. Other research avenues may include understanding how different age groups would experience online grocery shopping platforms when their contexts are personalized to them, such as saving money or obtaining increased quantities of products for the same amount of money.

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