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HEC MONTRÉAL

Age-related differences in the user experience of shopping for groceries online

Maya Saric

Directors

Constantinos Coursaris
HEC Montréal

Stefan Tams
HEC Montréal

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Résumé

L'espérance de vie est en croissance et ainsi, le nombre de personnes âgées s'élargit, nécessitant un accès facile à des produits de base tels que la nourriture. Dans une population qui vieillit rapidement, l'épicerie en ligne devient une ressource pratique qui est de plus en plus disponible. Cependant, on sait que la capacité cognitive des personnes âgées, à savoir leur capacité de mémoire de travail et leur vitesse de traitement, diminue naturellement avec l'âge et qu'elle est importante pour effectuer les calculs mentaux nécessaires à l'achat de produits alimentaires en ligne. Les personnes âgées ont une propension plus élevée à la charge cognitive, ce qui les rend moins probable de réussir à faire leurs courses en ligne de manière efficace. Les épiceries en ligne sont également plus difficiles en termes de quantité de calculs mentaux ou de complexité arithmétique. Cette étude vise donc à mieux comprendre comment et de quelle manière l'âge influe sur la performance en matière d'achats en ligne.

Pour répondre à notre question de recherche, des conditions de complexité arithmétique élevée et faible ont été créées sur des diapositives d'ordinateur statiques, reproduisant un calcul mental commun à une expérience d'achat de produits alimentaires en ligne. Dans le cadre d'une étude intra-sujet, 32 participants, moitié jeunes adultes et moitié adultes plus âgés, ont effectué des courses en ligne et répondu à des questionnaires après chaque condition. Ils ont également réalisé deux tests cognitifs, afin d'évaluer la capacité de la mémoire de travail et la vitesse de traitement. En résumé, nos résultats montrent que la capacité de la mémoire de travail a un impact direct sur la capacité en mathématiques et que la charge cognitive a un effet direct important sur les performances de l'épicerie en ligne. D'autres résultats et implications théoriques et managériales sont discutés.

Mots clés : courses en ligne, vieillissement, expérience utilisateur, capacité de la mémoire de travail, vitesse de traitement, auto-efficacité, capacité mathématique, charge cognitive, complexité arithmétique

Abstract

As average life expectancy increases, the average population age rises, resulting in an increased need to easily access basic goods such as food. In a rapidly aging population, online grocery shopping becomes a convenient and increasingly available resource. However, older adults' cognition, namely their working memory capacity and their processing speed, are known to naturally decline with age and are important in making mental calculations required in purchasing foods online. Older adults have a higher propensity to cognitive load, making them less likely to succeed in shopping for groceries online efficiently. Online grocery shopping is also more difficult in terms of its number of mental calculations, or in its arithmetic complexity. Thus, this study aims to further understand how and in what ways age affects online grocery shopping performance.

To answer our research question, high and low arithmetic complexity conditions were created on static computer slides, replicating a mental calculation common of an online grocery shopping experience. In a within-subjects study, 32 participants, half younger adults and half older adults completed online grocery shopping tasks and answered questionnaires after each condition. They were also asked to complete two cognitive tests, which would test for working memory capacity and processing speed. In summary, our findings show that working memory capacity has a direct effect on mathematical ability and that cognitive load has a strong direct effect on online grocery shopping performance. Further results, theoretical and managerial implications are examined.

Keywords: online grocery shopping, aging, user experience, working memory capacity, processing speed, self-efficacy, mathematical ability, cognitive load, arithmetic complexity

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I would like to thank my supervisors, Constantinos Coursaris and Stefan Tams for their guidance, feedback and encouragement. The Research Ops team at the Tech3Lab was also critical to my research. I would like to offer particular gratitude to Salima Tazi whose ongoing help, support and kindness has helped fuel not only my study, but which brought about a constant sense of curiosity, teamwork and thirst for knowledge at the laboratory. I would also like to thank statistician Carl Saint-Pierre, whose wealth of statistical knowledge and experience in supporting students has been instrumental to my thesis.

I am grateful to my family and friends for supporting me through this journey, with specific gratitude to family friend Nancy Barbiero, who has assisted me greatly with recruitment efforts and Richard Fenster, who has helped me more than he can know. A big thank you to the friends I have met thanks to this degree, among others Bella, Chantel, Lan-Chi, Julie, Mariana, Phuong, Erfan, Barbara and Kaja. We were able to support and encourage each other and I am forever grateful for it. Finally, this thesis is for all of the older adults I have worked with before and during the Covid-19 pandemic – particularly to those who I have gotten to know while waiting for online grocery queues. May more research continue to come for the user experience of older adults.

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Acronyms

SMI = SensoMotoric Instruments

AOI = Area of Interest

TEPR = Task-evoked pupillary response (the pupil's dilation as a result of increased cognitive load of a challenging task)

OSPAN = Operation Span Task (a cognitive task measuring Working Memory Capacity)

DSST = Digit Symbol Substitution Task (a cognitive task measuring Processing Speed)

OGS = Online Grocery Shopping

1. Introduction

1.1 Research Context

Shopping and other daily activities such as banking are becoming increasingly digital and we have become increasingly reliant on digital interfaces to meet our daily needs (Wavrock, Schellenberg & Schimele, 2022). The Covid-19 global pandemic added additional restrictions which resulted in many individuals shopping for their groceries online (Tyrväinen & Karjaluoto, 2022). However, not all individuals had the same familiarity with these websites and online grocery platforms were faced with a situation in which multiple types of users are now purchasing foods on the same websites all at once, all of which have different experiences and needs.

Older adults struggle more than younger adults to shop for groceries in-person than younger adults, given their increased propensity for health and mobility issues (Huang et al., 2012). However, how is their online grocery shopping experience? The Covid-19 pandemic highlighted the need for increased usability in purchasing from online groceries. Articles are appearing highlighting the lack of consultation of older users in the creation and upkeep of online grocery shopping websites (ex. Haire & Miller, 2020).

Older adults also have natural cognitive changes which may disadvantage them in online tasks, including mental calculations and other short-term memory tasks on digital interfaces (Rozencwajg et al., 2010). Online grocery shopping utilizes more involved thinking and problem-solving processes than other types of shopping, due to its wealth of numerical information in the forms of prices, weights and discounts (Desrochers et al., 2019). Older adults do not shop for groceries online as much as younger adults, despite how much this can help them in their daily activities (Garcia, 2018). Given all of these factors potentially contributing to older adults shopping for groceries online less and the lack of literature honing in on all of the aforementioned factors, this thesis aims to understand how age affects online grocery shopping performance.

1.2 Research Question

The overarching research question for both articles is as such:

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

With a significant amount of literature present on grocery shopping and even on online grocery shopping, few studies hone in on the particularities of aging and how natural age-related cognitive changes affect online grocery shopping performance. We must also consider realities characteristic to older adults, such as how they do not have as much exposure to modern digital interfaces the way their younger peers have, for example. Understanding the mechanisms of how age affects performance in online grocery shopping would thus be pertinent.

A within-subjects design was created with stimuli of both a low arithmetic complexity and high arithmetic complexity. In other words, one condition would involve less challenging mental calculations and information processing, and the other would involve more challenging mental calculations and information processing. The stimuli for each condition consisted of realistic purchasing scenarios where the user was instructed to maximize the amount of foods they can purchase with a given budget. There was always one correct answer from 1 to 5 for each stimulus. Participants were half younger adults and half older adults. Participants were able to participate in their home setting if they could not or would not come to HEC Montréal. Eye tracking was used to later analyze pupillometry data for numerical areas of interest.

HEC's Ethics Review Board, the CER (Comité d'éthique de la recherche) approved this study with code #2023-5016. The documentation is provided in appendix H. This study was made possible through a NSERC grant from the Industrial Research Chair in User Experience, grant number NSERC IRC 505259-16, as well as through funding from PROMPT (R2185; R2188A; R2106; R2882).

1.3 Article 1

Article 1 presents an individual-based mechanism in explaining the effect of age on online grocery shopping. Therefore, it considers age, natural cognitive changes and their involvement in online grocery shopping performance among older and younger adults.

1.4 Article 2

Article 2, on the other hand, focuses on task-focused mechanisms to explain the effect of age on online grocery shopping performance. It explores how arithmetic complexity affects cognitive load through exposure to the stimuli and how cognitive load affects online shopping performance. As with article 1, article 2 also includes both younger and older participants. A shortened version of paper 2 was submitted and accepted to the SIGHCI Pre-ICIS conference in Hyderabad, India, to be presented on December 10, 2023. Its reference is included in appendix G.

1.5 Thesis structure

This thesis is structured as follows. Chapter one will be a brief introduction to the topic, leading into chapters 2 and 3, which present papers 1 and 2. Please note that both papers are based off of one data collection. As a result, there is some overlap. Paper 1 focuses on aging, cognitive processes (in this case, processing speed and working memory capacity), mathematical ability, self-efficacy and online grocery shopping performance. Paper 2 shifts its focus to the involvement of arithmetic complexity and cognitive load in aging, in addition to self-efficacy and online grocery shopping performance. Finally, chapter four ends with a conclusion in which main findings, limitations and contributions will be revisited.

1.6 Contributions

Table 1 highlights the contributions in completion of this thesis.

Table 1: Contributions in thesis realization

Step in the process	Contribution
Research question	60% Searching for topics and areas of interest, ongoing discussions with supervisors – 70%

	Elaboration of the research model – 50%, with assistance from supervisors
Literature review	100% Reading relevant literature and writing the theoretical foundations.
Conception and experimental design	Applying to the ERB (Ethics Review Board) – 100% Developing experimental design – 75% Determining operational stimuli – 100% Designed the experimental stimuli and created the mathematical equations, ensuring that there was 1 correct answer per stimulus. Questionnaires – 85% Searching for validated questionnaires for appropriate research variables, creating questionnaires on Qualtrics.
Pre-tests	100% I pre-tested the experimental conditions to ensure the low arithmetic complexity and high arithmetic complexity results were significantly different (n = 8).

Recruitment & Data Collection	Recruiting participants - 100% I advertised the study near the university with a poster and a QR code in order to recruit younger adults and made use of the university research panel. I also met with private seniors residence directors and leisure center directors in order to advertise the study for older adults. Conduct the study – 100% I traveled to all participants who preferred completing the study in their home environment and conducted the study on all participants.
Data Analysis	63% ● Extracting and cleaning all data – 100% ● Analyzing paper 1 ANOVA results on SAS – 75% ● Analyzing paper 2 results – 15% ○ Tech3Lab statistician assisted by manually inputting the process to fit the research model. With guidance and assistance from Tech3Lab statistician.
Writing the thesis	100% With guidance and feedback from supervisors and SIGHCI[1] pre-ICIS[2] reviewers.

[1] Special Interest Group on Human Computer Interaction
[2] International Conference on Information Systems

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2. Article 1

The impact of age-related cognitive changes on online grocery shopping performance

Maya Saric, Constantinos Coursaris, Stefan Tams

Tech3Lab, HEC Montréal, Montréal, Canada

Abstract

With an aging population worldwide, there is further need for access to essential goods such as groceries. However, older adults' working memory capacity and processing speed, two cognitive processes, naturally decline. These processes are understood to impact mathematical ability, which is needed when making mental calculations such as quantities of foods, savings, etc. The purpose of this study is to thus to understand how and in what ways age affects online grocery shopping performance. Our findings confirm that age has a significant negative impact on working memory capacity and processing speed, which are both understood to impact task performance. However, working memory capacity was more closely implicated in the process impacting one's online grocery shopping performance, directly affecting mathematical ability. Mathematical ability was also found to influence online grocery shopping performance. Finally, self-efficacy was found to positively moderate the relationship between mathematical ability and self-reported online grocery shopping performance. Theoretical and managerial implications are explored.

Keywords: online grocery shopping, aging, user experience, working memory capacity, processing speed, self-efficacy, mathematical ability

2. 1. Introduction

It is projected that the worldwide proportion of adults 60 years and older will increase from 12% in 2015 to 22% in 2050 (WHO, 2021). In Canada, as of July 2022, there were over 7 million senior citizens reported and this number is expected to continue to increase (Statistics Canada, 2023). Life expectancy in Canada is also steadily increasing (Public Health Agency of Canada, 2021).

Several changes occur during the process of normal aging. We can observe decreases in thinking speeds and working memory (University of California San Francisco, n.d.; Rozencwajg et al., 2010). Older adults' cognitive changes differ based on the type of cognitive ability (Rozencwajg et al., 2010). Notably, it appears that older adults experience a steadier decline with regards to their processing speed, thus impacting arithmetic skill more so than other skills (Rozencwajg et al., 2010).

Concurrently, for both younger and older adults, there is an obvious need to easily purchase groceries and other daily essentials. However, in an aging population, it is more difficult to access essential goods, due to difficulties with transportation (Huang et al., 2012), reduced mobility (Huang et al., 2012) and fear of the pandemic (Palmer et al., 2021). While a small percentage of older adults used online grocery platforms in pre-pandemic times (Gavin, 2020 in Kovalenko, 2021; International Food Information Council Foundation, 2018), since the advent of the pandemic, trends have shown a steady increase in individuals shopping online (Lebow, 2021). This holds true for essentials, such as grocery shopping (Goldman, 2021; Yuen, 2023). Though older adults continue to purchase groceries online less than younger adults, the number of older adults shopping virtually is steadily increasing and the generational gap is decreasing (Garcia, 2018). Additionally, older adults who have tried online grocery shopping during the pandemic are more likely to continue using OGS post-pandemic, either as primary or supplementary shopping (Shen, Namdarpour & Lin, 2022).

While there is an interest, shopping for groceries online is still more difficult for older adults. For example, in one study with older adults who report ease of use with technologies, these users took twice as long to order their groceries online than their younger counterparts (Sjölinder et al., 2003).

Another study noted that it took older adults 3 or more orders for them to begin feeling at ease with the process of ordering groceries online (Haire & Miller, 2020).

Older users have specific design needs (Kane, 2019). However, online grocery platforms are not made with older adults in mind. They also may not be consulted or implicated in the design process of OGS platforms, despite increasingly using them (Haire & Miller, 2020). This is the case for many technologies (Gorski, 2005). Thus, older adults continue to face many barriers and obstacles in using online grocery shopping regularly and efficiently (Haire & Miller, 2020).

Older adults present natural changes in their working memory capacity and processing speed, both of which are involved in task performance, particularly when faced with mathematical calculations (Rozencwajg et al., 2010). Simultaneously, online grocery shopping is on the rise (Yuen, 2023). Shopping for groceries online has been shown to be more challenging than other types of online purchases, due to the presence of multiple numerical information, such as food weights, discounts and quantities (Desrochers et al., 2015). In tandem, older adults' lesser exposure to technologies, including online shopping, is accompanied by a lower digital self-efficacy (Czaja et al., 2006). Few studies have focused on studying the effects of online grocery shopping tasks (Desrochers et al., 2015). Therefore, we pose the following research question:

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

In sum, our results demonstrate that age has a significant and direct negative impact on both working memory capacity and processing speed. However, only working memory capacity has an impact on mathematical ability. Additionally, mathematical ability has a negative effect on online grocery shopping performance and self-efficacy has a moderating effect on this relationship.

The paper will be structured as follows. First, we will present the literature review, which will cover the theoretical foundations and the subsequent research hypotheses. Second, the methodology will be presented, including the experimental design and the operationalization of the research variables. Third, the results will be introduced. Next, we will put forward a discussion based on the results presented and end with a conclusion.

2.2 Literature Review and Hypotheses

2.2.1 Information Processing & Memory Creation

Information processing is widely viewed as disjointed and that information is processed in numerous steps. This interpretation is known as the stage theory model (Atkinson and Shiffrin, 1968). First, sensory memory takes place as we are exposed to new stimuli. If this new information is not quickly absorbed, it is rapidly forgotten and lost. This process happens within seconds (Lutz & Huitt, 2003). However, if this information continues to be actively processed, it reaches short-term memory or working memory (Lutz & Huitt, 2003). At this stage, new information is actively being treated and manipulated and lasts for a maximum of roughly half a minute (Lutz & Huitt, 2003). Finally, some information may be processed by short term memory and be retained and consolidated in the final stage of memory formation, long-term memory (Lutz & Huitt, 2003). Long-term memory "is [a] more permanent store in which information can reside in a dormant state – out of mind and unused – until you fetch it back into consciousness" (Abbot, 2002, p. 1 in Lutz & Huitt, 2003). Therefore, it amasses years of consolidated knowledge and memories through one's lifetime (Lutz & Huitt, 2003).

2.2.2 Aging, Working Memory Capacity and Processing Speed

Working memory capacity is defined as the "hypothetical cognitive system responsible for providing access to information required for ongoing cognitive processes [where one's individual differences] reflect the limited capacity of a person's working memory" (Wilhelm et al., 2013). The concept of working memory capacity arose from short-term memory analysis and became an important information processing concept (Baddeley, 2010). In fact, working memory capacity is a limited resource for individuals of all ages, but it is particularly affected by aging (Hertzog et al., 2003). Though it is recognized that there is a noted decline in working memory capacity in normal aging, the mechanisms are complex and multicausal (Park et al., 2002). It is also understood that working memory capacity is task dependent and is affected by complex arithmetic tasks (Turner & Engle, 1989). Psychologists Baddeley & Hitch's model of working memory was particularly influential in explaining cognitive changes through aging, and involves the interplay between three cognitive components (1974). The interactions between these systems include active processing of information, in which the central executive, the primary system, issues information to be processed and stored by the two subsystems (1974). To further elaborate, in aging, working memory resources are more difficult to mobilize (Salthouse, 1996; Arguello & Choi, 2019). This further impacts tasks involving fluid memory (Rozencwajg et al., 2010) including decision-making, due to its requirements to manipulate information (Del Missier et al., 2013). Those who are older are thus further disadvantaged in tasks involving working memory capacity than their younger counterparts (Verhaeghen et al., 2019).

On another hand, Timothy Salthouse's Processing Speed theory offers an alternative explanation to natural age-related cognitive declines. Processing speed is defined as a measure of the time required to respond to and/or process information in one's environment (Horning & Davis, 2012). Salthouse theorized that as we age, our processing speed slows, due to an increased difficulty in processing as much information at a time as a younger person would (Salthouse, 1996). He further explains that this fluid cognition is slowed due to older adults' difficulty with processing new information as rapidly as their younger peers. Additionally, older adults demonstrate greater difficulty in retrieving the information from prior stimuli, due to the extended time required to process previous information (Salthouse, 1996). It is also to be noted that the older an individual, the more significantly impacted is their processing speed (Salthouse, 2000). Finally, processing speed is linked to mental arithmetic and is understood to be a predictor of performance when faced with mathematical tasks (Rozencwajg et al., 2010).

Given this information, we propose the following hypotheses relating age, processing speed and working memory capacity:
H1: Age negatively impacts processing speed.
H2: Age negatively impacts working memory capacity.

2.2.3 Aging & Mathematical Ability

Mathematical ability refers to the "verbal and mathematical ability to follow directions or make calculations [...]" (Gatewood, Perloff & Perloff, 2000). In order to complete arithmetic calculations, one must use their working memory (Cragg et al., 2017), which as previously outlined, naturally declines with age (Hertzog et al., 2003). Some researchers found that the central executive is hindered when confronted with mathematical tasks, particularly when an individual is confronted with a mathematical task involving counting or decomposition (ex. 24 + 41 = 20 + 40 + 4 + 1 = 65) (Cragg et al., 2017). Children are likely to fare worse with mathematical tasks until they learn more complex procedures and are thus prone to overexerting their working memory capacity (Cragg et al., 2017). However, once adults develop these competencies, they may be at an advantage until they reach older adulthood when cognitive losses impact their working memory capacity. Numerical processing speed is also found to impact mathematical ability, with an elevated numerical processing speed leading to mathematical achievement (Lambert & Spinath, 2018). We previously outlined the natural decline in processing speed in the aging process. The involvement of cognitive processes such as working memory capacity and processing speed in arithmetic processing and mathematical ability logically may then impact task performance, particularly if the task employs mathematical calculations.

Due to the involvement of both processing speed and working memory capacity in mathematical ability, we propose the following hypotheses for our research question:
H3: Processing speed positively impacts mathematical ability.
H4: Working memory capacity positively impacts mathematical ability.

2.2.4 Age, Online Grocery Shopping & Task Performance

While aging is known to impact IT-related task performance (Tams, 2022), studies considering the specificities of a user's age, including his or her natural cognitive changes, are found to be insufficient in comparison to task and technology focused studies (Tams, 2022).

Older adults behave differently than their younger counterparts while shopping online (Lesakova, 2016). Older adults have used online grocery shopping less than younger adults (Bezirgani & Lachapelle, 2021a; Bezirgani & Lachapelle, 2021b; Hanus, 2016). Other studies on online grocery shopping have shown that users with less experience on OGS platforms performed more poorly and rated the interface as less usable than users with more experience with online grocery shopping (Freeman, 2009). They also take significantly more time to complete their online grocery shopping than younger adults (Sjölinder et al., 2000; Lesakova, 2016). They also struggle more with the navigation of visuospatial elements, such as the page layout and the grouping of visual categories (Sjölinder et al., 2000). Other studies show that older adults can be better performers at tasks such as grocery shopping, due to their increased decision-making abilities (Kim & Hasher, 2005). However, globally, older adults are well-documented to perform less well in problems involving product price information and mental manipulation, due to their natural changes in memory (Zeithaml & Fuerst, 1983).

Furthermore, younger adults and older adults appear to have different goals in their grocery shopping experiences (Lesakova, 2016), which may lead to a desire to shop online for groceries. Younger adults value saving time and convenience particularly due to their children and families (Morganosky & Cude, 2000) and older adults value saving money, reducing the need for physical inconveniences such as carrying heavy items or reaching high shelves or deep freezers (Lesakova, 2016). However, despite differences in their goals, all users ultimately wish for a smooth user experience, minimizing pain points at each step of the OGS experience, including the browsing and selection of grocery products (Giroux-Huppé et al., 2019). Additionally, multiple mental calculations and ambiguity in terms of pricing is known to be a pain point, elevating the user's cognitive [load] (Desrochers al., 2015). As previously mentioned, mathematical and arithmetic tasks are known to be more difficult for older adults (Lemaire & Arnaud, 2008; Rozencwajg et al., 2010).

Thus, we propose the following hypothesis to answer our research question:
H5: Mathematical ability positively affects performance on shopping tasks.

2.2.5 Aging & Self-Efficacy

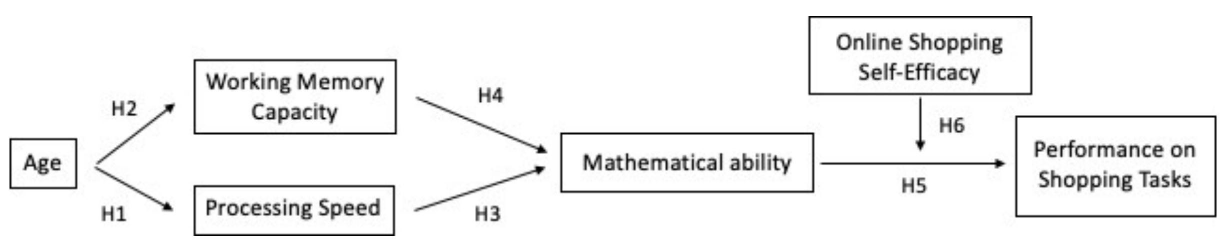
Self-efficacy is understood as an individual's "beliefs in his or her capacity to organize and execute behaviors required to produce specific performance attainments" (Bandura, 1977, 1986, 1997). In older adults, a lower computer self-efficacy is more common than in younger adults, partly because of their lesser exposure, on average, to technologies, including computers and the Internet in general (Czaja et al., 2006). Older adults report feeling less confident in their abilities to navigate the Internet and use computers, even when these technologies can aid them in daily activities such as banking and shopping (Czaja, et al., 2006). Self-efficacy is found to motivate users to make greater efforts in their tasks (Tams, 2022). Interestingly, both younger and older adults with particularly high self-efficacy scores have shown to overestimate their actual performance (Schreder et al., 2013). There is also some evidence that challenging tasks may lead to underestimating one's performance, as people may doubt themselves when the task is challenging (Kahneman, 2011).

To this author's knowledge, no literature has touched upon the effect of self-efficacy on older adults in an online grocery shopping context, particularly when also considering age-related cognitive changes and task complexity. However, given the general data with older adults and technologies, it is logical to understand that self-efficacy may impact performance. Thus, we end with our final hypothesis:

H6: Self-efficacy moderates the relationship between mathematical ability and performance on online shopping tasks.

Figure 1 reflects the model incorporating the preceding hypotheses:

Figure 1: Proposed research model



2.3. Methodology

2.3.1 Setup

An IBM (International Business Machines) laptop was used to run the study. TeamViewer was used in order to mirror the participant's screen on the moderator's computer, in order for them to manage the flow of the tasks. The moderator and the participant were seated close to one another, without being face to face.

2.3.2 Experimental Design

Arithmetic complexity refers to the difficulty of a given calculation or mental exercise (Campbell, 2005). Many factors may influence arithmetic complexity, such as changing the way product price information is shown (e.g. weighed as opposed to individual) and using decimals instead of integers, for instance.

To test the hypotheses, a reduced factorial design (arithmetic complexity: price per product or price per weight & arithmetic complexity: integers or decimals) within-subjects design was conceived. As shown in table 2, two of the conditions (price per weight x decimals & price per product x integers) were retained, as they reflect the extremes of difficulty levels. Only the extreme conditions (high and low) were retained in order to assess the interaction effect between the two variables at their extremes. A low complexity condition has integers and prices per unit (for example, 5$ per bag of oranges) as opposed to high arithmetic complexity, which includes both decimals and a cost per weight (for example, 2.25$ per 100g of oranges). Prior to running the test on participants, pre-tests were conducted which showed a significant difference in performance between the low arithmetic complexity condition and the high arithmetic complexity condition. The tasks included four stimuli per condition and the conditions were randomized. All participants were exposed to both conditions after a practice trial. Finally, we can consider age as an experimental selection, since prerequisites for participating in the study was to fall under the age brackets selected for younger adults and older adults.

Table 2: Experimental design

	Price per product	**Price per weight**
Integers	Low arithmetic complexity Younger, older	N/A
Decimals	N/A	High arithmetic complexity Younger, older

2.3.3 Participants

Thirty-two participants who reside in Montréal, Québec took part in the study. Approximately half were younger adults (17 out of 32 being between the ages of 18 and 35 years of age), the other half being older adults (15 out of 32 being 60 years or older). These age ranges were selected in advance, reflecting the changes in cognitive abilities observed in the literature on aging, as well as demonstrating a wide enough gap in years between the two groups. Younger participants ranged from 21 to 32 years of age ($\bar{x} = 26$, $\sigma = 4.50$) and older participants ranged from 60 to 78 years of age ($\bar{x} = 66$, $\sigma = 6.43$).

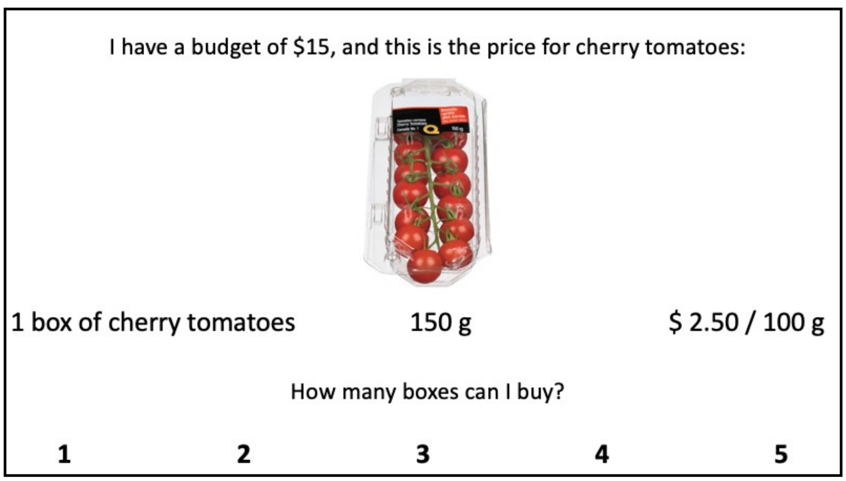
Recruitment methods varied and included the laboratory research panel, advertising the study near HEC Montréal with a QR code as well as in autonomous and semi-autonomous older adult residences and activity centers and snowball sampling. In order to make participation in the study more accessible to older adults, particularly to those in their seventies and beyond, participants were able to select whether this moderator would meet them in their home setting or if they were able to and wished to do so, to participate at HEC Montréal. This study was approved by the Ethics Review Board at HEC Montréal, #2023-5016.

2.3.4 Experimental Task and Stimuli

For the focus to remain solely on processing of numerical information and text necessary to solve the tasks without potentially confounding variables such as branding and colors, all stimuli were kept bare with a white background and no visible branding. All stimuli are shown in appendix A. This also facilitated extraction of data on the SMI eye tracker, in which a gaze on a static element was easier to capture than an actual website.

Each stimulus had a bare background with text in a large black font and had nondescript images of produce with little to no visible branding. Participants were shown instructions, which specified that their task was to maximize the amount of produce they can purchase with their given budget. In figure 2, this would be 15$. An image was shown of the produce they were purchasing in the task, as well as the quantity and the weight. In figure 2, the quantity is 1 box of cherry tomatoes and the weight corresponds to 150 g. Next, the product price information was displayed, as demonstrated by $2.50/100 g in figure 2. In this example, users must do the mental calculation to know the cost of 1 box of cherry tomatoes, which weighs 150 g and then must calculate how many boxes they can purchase with their budget of 15$. When users were instructed to select the maximum amount of produce, they can purchase with the given budget, they were informed that the answer is always from 1-5 as shown on figure 2 and in every stimulus presented. Costs were inspired by Montreal food retailers. All of the above information was always provided to the participant, even if it was not relevant. For instance, if their budget is of 5$ and 1 orange which weighs 0.31 lb costs 1$, the weight is not required to make the calculation and complete the task. However, in other instances, weight is required as the product is in bulk or weighed, emulating an actual grocery shopping experience, where there are both prepackaged goods and weighed goods.

Figure 2: An example of a stimulus in the high arithmetic complexity condition

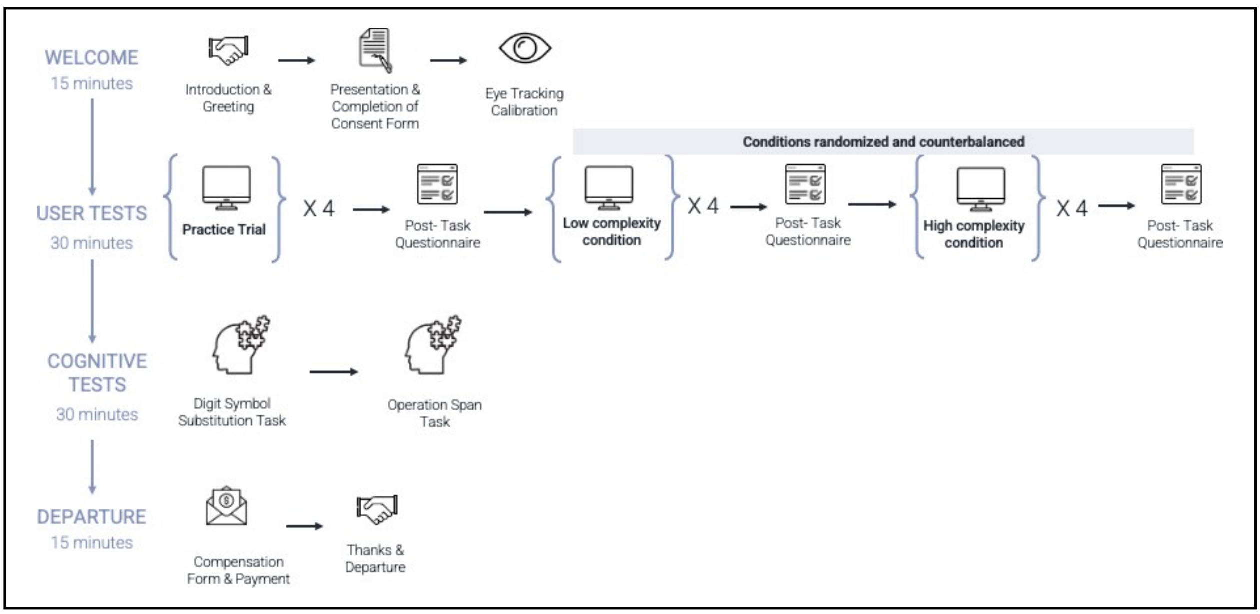


2.3.5 Procedure and Materials

Since participants were given the option of participating either in their home environment or on the HEC Montréal campus, this researcher met the participant in their selected location. The laptop and eye tracker were either set up prior to the participant arriving if they participated on campus and if this was not the case, the set up was completed while the participant was reading the consent form. As illustrated in figure 3, after the consent form was signed, the eye tracker was calibrated. The participant then had a practice trial, then completed the two sets of online grocery shopping tasks. The practice trials were created in order to reduce the risk of a learning effect as well as providing an opportunity for the participant to feel at ease and comfortable with the task at hand.

Users were asked to both say their answer out loud (i.e. from 1 to 5) and to gaze at their selected answer on the screen for the eye tracker to detect. When the participant finished one condition, they were instructed to complete a post-task questionnaire. Finally, the study ended with the participant taking part in two cognitive tests. The Digit Symbol Substitution Task (DSST) (National Institute on Aging, 2005) is a paper test administered to the participant and the Operation Span Test (OSPAN) (Turner & Engle, 1989) was completed on the laptop they used for the online grocery tasks. Lastly, the participant was asked to read and sign the compensation form and was given 20$ cash for their participation in the study. In its entirety, the study lasted approximately 1 hour and 30 minutes.

Figure 3: Experimental procedure



2.3.6 Measures

Millisecond's Inquisit was used in order to employ the Digit Symbol Substitution Task (DSST), a cognitive test measuring one's working memory capacity. Qualtrics was used in order to display all questionnaires. All questionnaires are shown in appendix B.

2.3.6.1 Operationalization of Research Variables

Table 3: Main study constructs and items for objective and subjective measurements

Objective Measurements			
Construct	**Definition**	**Measure**	**Source**
Mathematical Ability	"The ability to undertake numerical and algebraic calculation with fluency and accuracy" (Hewitt, 1996).	Percentage of correctly solved math problems during the OSPAN[3] test.	Operation Span Task (Engle & Turner, 1989 via Inquisit by Millisecond, Seattle, WA, USA)
Processing Speed	"The speed of processing information and interpreting it" (Salthouse, 1996).	DSST[4] score	Digit Symbol Substitution Test (subset of Weschler Adult Intelligence Scale, National Institute of Aging)
Working Memory Capacity	"The amount of information one can store in their memory at one time in order to manipulate this information" (Baddeley & Hitch, 1974).	OSPAN score	Operation Span Task (Engle & Turner, 1989 via Inquisit by Millisecond, Seattle, WA, USA)
Age	-	Chronological age in years.	-
Subjective Measurements			
Construct	**Definition**	**Measure**	**Source**
Task Performance	"The degree that users are able to meet task goals" (Burton-Jones and Straub 2006 in Tams, 2022).	Please rate the extent to which you agree or disagree with the following statements: 1. I have completed my assigned task (selecting quantities of food) very effectively. 2. I have performed the task (selecting quantities of food) very well. 3. I have fulfilled the task responsibilities (selecting quantities of food) very effectively.	Questionnaire in Tsai, Chen & Liu, 2007
Self-Efficacy	"A person's belief in their ability to execute behaviors necessary for performance attainment" (Bandura, 1977).	To what extent do you agree or disagree with the following statements: 1. I have the ability to be very good at using online grocery shopping platforms. 2. I have the ability to excel at using online grocery shopping platforms. 3. I have the ability to perform very well when using online grocery shopping platforms.	Questionnaire in Tams, 2022 from Bandura, 2006; Compeau & Higgins, 1995; Marakas et al., 1998

[3] Operation Span Task
[4] Digit Symbol Substitution Test

2.3.6.1.1 Mathematical Ability

Mathematical ability refers to an individual's level of proficiency in mental arithmetic, including the ability to properly estimate and use appropriate strategies to solve an equation (Siegler & Booth, pp. 197-212 in Campbell, 2005). As shown in table 3, it is measured through the percentage of correctly solved mathematical problems in the OSPAN task. The Operation Span Task includes testing on mathematical proficiency, with a focus on short-term memory, due to the mathematical equations being displayed in a time constraint (Unsworth et al., 2017). It thus renders it a viable test for both working memory capacity and mathematical ability, which is included as a sub score of the OSPAN task (Jonsson et al., 2021).

2.3.6.1.2 Cognitive Processes: Processing Speed & Working Memory Capacity

Processing speed refers to the time required to execute cognitive processes (Salthouse, 1996). Among the common means of measuring this variable is the digit symbol substitution task, or DSST (Jaeger, 2018). The DSST is a cognitive test consisting of a series of symbols and their corresponding numbers, where the individual is tasked to match as many numbers with their associated symbols in empty spaces provided for this exercise in 90 seconds (Rosano et al., 2016). The digit symbol substitution task is considered a sensitive cognitive testing tool (Chen et al., 2020) with high retest reliability (Rosano et al., 2016). The more symbols the individual is able to match with their corresponding digits in the allotted time, the higher is their score, which indicates an increased processing speed (Jaeger, 2018).

On the other hand, working memory capacity encompasses the "individual differences reflecting the limited capacity of a person's working memory (...) [of a] cognitive system responsible for providing access to information required for ongoing cognitive processes" (Wilhelm et al., 2013). The Operation Span task (OSPAN) is a commonly used cognitive task to measure working memory capacity (Unsworth et al., 2005). The OSPAN is recognized as a reliable, consistent (Unsworth et al., 2005) and valid (Conway et al., 2005) testing tool. It consists of a series of mathematical equations interspersed with sequences of letters, which the individual is asked to remember in order, all while being interrupted with the aforementioned arithmetic equations (Turner & Engle, 1989). The more letters the individual is correctly able to remember and the higher their percentage of correctly solved mathematical equations results in a higher OSPAN score, thereby indicating a more elevated working memory capacity (Turner & Engle, 1989).

Age was measured as an experimental selection. It was chronological and measured in years. In screeners for booking of the study, participants were only accepted if they were between 18 and 35 years of age (younger adults) or 60 years and older (older adults). These age clusters were predetermined based on literature on cognitive aging.

2.3.6.1.3 Task Performance

Task Performance is defined as the degree that users are able to meet task goals (Burton-Jones and Straub 2006). In this study, we honed in on the user's perception of their task performance. Perceived performance was measured via a validated questionnaire by Tsai, Chen & Liu (2007).

2.3.6.1.4 Self-Efficacy

Since technology self-efficacy is a stable, situation-specific trait (Thatcher & Perrewé, 2002), participants rated their online grocery shopping self-efficacy before engaging in the online grocery shopping tasks.

2.3.7 Data Extraction and Analysis

Eye tracking data was exported through SensoMotoric Instruments (SMI) BeGaze, while the SMI Experiment Center software was used to input the stimuli. Millisecond Inquisit cognitive test scores and Qualtrics questionnaire scores were extracted and merged into Excel spreadsheets. The dataset was merged to an n = 32, which was necessary to analyze the entire model at a time via a Hayes model and also due to the presence of repeated measures. All results were analyzed on IBM SPSS version 28, by means of a process procedure written by Andrew F. Hayes which was brought to SPSS on version 4.2 beta.

2.4. Results

2.4.1 Descriptive statistics

Below are the global descriptive statistics of all of the variables measured in the course of this study, i.e. working memory capacity (WMC), processing speed (PS), mathematical ability, self-efficacy, as well as subjective task performance (Subj Perf).

Table 4: Global descriptive statistics

	WMC [5]	**PS** [6]	**Math Ability**	**Self Efficacy**	**Subj Perf** [7]
Means	31.750	59.156	91.459	5.677	5.275
St. Dev.	21.393	13.712	8.412	1.042	1.027
Minimum	3	34	65.33	3.333	3.500
Maximum	75	83	100.00	7.000	7.000

NB: n = 32

As shown in table 4, working memory capacity scores ranged from 3 % to 75 % ($\bar{x}$ = 31.75 %), whose scores were significantly lower than processing speed scores, which ranged from 34 % to 83 % ($\bar{x}$ = 59.16 %). Self-efficacy scores ranged from 3.33 to 7 out of 7, with an average of 5.68. Self-reported task performance scores averaged in at 5.27/7 (min = 3.50/7, max = 7/7).

Table 5: Pearson Correlations of global results

	WMC	$p-value^1$	**PS**	$p-value^1$	**Math Ability**	$p-value^1$	**Self-Efficacy**	$p-value^1$	**Subj Perf**
WMC	1.000								
PS	0.385	0.029	1.000						
Math Ability	0.383	0.030	0.117	0.524	1.000				
Self-Efficacy	-0.027	0.884	0.236	0.193	0.115	0.530	1.000		
Subj Perf	0.052	0.778	-0.282	0.118	0.264	0.144	-0.060	0.746	1.000

[5] Working Memory Capacity
[6] Processing Speed
[7] Subjective Performance

1. Bilateral level of significance

Table 6: Pearson Correlations of younger adults and older adults

	WMC	$p-value^2$	PS	$p-value^2$	Math Ability	$p-value^2$	Self-Efficacy	$p-value^2$	Subj Perf	$p-value^2$
WMC	1.000		-0.090	0.749	0.482	0.069	-0.079	0.780	0.051	0.857
PS	0.351	0.167	1.000		0.261	0.347	0.157	0.577	-0.148	0.599
Math Ability	0.410	0.102	0.190	0.465	1.000		0.213	0.445	-0.230	0.410
Self-Efficacy	-0.396	0.116	-0.405	0.107	0.087	0.740	1.000		-0.196	0.485
Subj Perf	0.212	0.414	-0.189	0.468	0.553	0.021	0.329	0.198	1.000	

1. Lower correlation matrix corresponds to younger participants and upper correlation matrix corresponds to older participants
2. Bilateral level of significance

As noted in tables 5 and 6, working memory capacity was found to be significantly lower in older adults than in younger adults (p = 0.0327). Processing speed is also significantly lower in older adults than in younger adults (p = < 0.0001). Self-efficacy scores were higher in younger adults than in older adults (p = 0.025). Interestingly, self-reported performance scores were comparable in younger adults and in older adults.

Table 7: Descriptive statistics and independent sample U-tests of younger participants and older participants

	Younger		Older		Mann-Whitney test	Interpretation
	Means	*Std. Dev.*	*Means*	*Std. Dev.*	*p-value*[1]	
	N_{obs}=17		N_{obs}=15			
WMC	39.235	22.387	23.267	17.190	0.033	Significantly different between younger and older
PS	68.176	10.045	48.933	9.498	< 0.0001	Significantly different between younger and older
Math Ability	91.059	9.212	91.912	7.700	0.780	Not significantly differentbetween younger and older

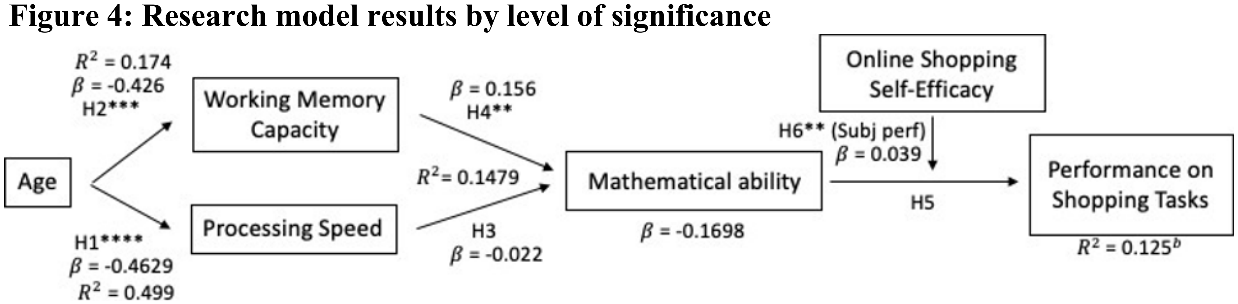
Self Efficacy	6.059	0.700	5.244	1.211	0.025	Significantly different between younger and older
Subj Performance	5.056	1.104	5.523	0.905	0.204	Not significantly different between younger and older

1. Bilateral level of significance test of the Mann-Whitney

As shown in table 7, when comparing the younger and older adults, both working memory capacity and processing speed are significantly different between younger adults and older adults (p = 0.033 for WMC; p = < 0.0001 for PS). For both scores, they are significantly lower for older adults than for younger adults. Both mathematical ability and subjective task performance are similar among younger adults and older adults. However, self-efficacy is significantly different among the two, with younger adults having a significantly higher self-efficacy than older adults (p = 0.025).

2.4.2 Hypothesis testing

Figure 4: Research model results by level of significance



Notes:

* ≤ 0.1

** ≤ 0.05 (0.05 - 0.10)

*** ≤ 0.01

**** ≤ 0.001

a = r^2 of self-efficacy, mathematical ability & the interaction of the two

b = r^2 only for the interaction

Figure 4 depicts the results also shown in table 8, which will be presented below. Please note that all p-values are divided by two, as directionality was stated in advance.

Table 8: Results from Hypothesis Tests

Hypotheses		R^2	coeff	p-value	Interpretation
H1	Age negatively impacts processing speed scores.	0.4993	-0.4629	0.00	Supported
H2	Age negatively impacts working memory capacity scores.	0.1738	-0.426	0.0176	Supported
H3	Processing speed scores positively impact mathematical ability scores.	0.1479 (PS & WMC)	-0.0221	0.8475	Not supported
H4	Working memory capacity scores positively impact mathematical ability scores.	0.1479 (PS & WMC)	0.1561	0.0412	Supported
H5	Mathematical ability positively affects self-reported performance on shopping tasks.	0.2031 (MA & S-E)	-0.1698	0.0981	Not supported
H6	Self-efficacy positively moderates the relationship between mathematical ability and self-reported performance on shopping tasks.	0.2031 (MA & S-E)	0.039	0.0453	Supported

As shown in table 8, age has a very significant negative impact on processing speed ($p = 0.00$). Therefore, the older one gets, the lesser their processing speed and in a very significant way. This shows support for H1. Age also has a significant negative impact on working memory capacity ($p = 0.0176$). In other words, the older one gets, the lesser their working memory capacity. Therefore, there is support for H2. Processing speed does not have an effect on mathematical ability scores ($p = 0.8475$), thus making H3 unsupported. However, working memory capacity does have a positive effect on mathematical ability ($p = 0.0412$). This shows support for H4.

Interestingly, while it was hypothesized that mathematical ability would positively influence performance scores on online grocery shopping tasks, mathematical ability was instead found to have a negative effect on participants' perceived performance ($p = 0.0981$, $r^2 = -0.1698$). H5 is therefore not supported, as the predicted direction was not demonstrated in the results. In other words, when a participant's mathematical ability was 1 score lower, he or she rated their performance as 0.1698 points higher (out of 7) after having completed the online grocery shopping task. Finally, self-efficacy was found to moderate the relationship between mathematical ability and perceived performance ($p = 0.0453$, $r^2 = 0.039$) (H6 supported).

2.5. Discussion

2.5.1 Results overview

Results show that as expected, older adults have significantly lower processing speed and working memory capacity than younger adults. Their self-efficacy scores are also lower than their younger peers. However, mathematical ability and online grocery shopping performance were comparatively similar.

Additionally, our results confirm that age does have a significant and negative impact on both processing speed and working memory capacity, two cognitive processes involved in learning and mathematics, among others. This shows support for hypothesis 1 and 2. However, only working memory capacity showed to have an impact on mathematical ability, which is required for mental calculations often used in online grocery shopping. As such, hypothesis 3 is unsupported and hypothesis 4 is supported. Interestingly, those with a high mathematical ability were found to rate their performance on online grocery tasks as lower and vice versa. This renders hypothesis 5 as unsupported, though it is significant in the opposite direction than predicted. Additionally, self-efficacy, the degree of confidence in one's ability to perform well, somewhat strengthened the relationship between mathematical ability and online grocery task performance. Hypothesis 6 thus shows support.

2.5.2 Discussion

Our results show that age has a significant and direct impact on both working memory capacity and processing speed. This is consistent with previous findings (for example, Hertzog et al., 2003; Salthouse, 2000). In other words, the older an individual, the more likely they have difficulty manipulating and treating short-term information, and the more likely they are to process information more slowly. Working memory capacity was found to have a direct impact on mathematical ability, which is congruent with previous findings. Previous studies have shown this cognitive capacity is intimately tied to complex mathematics (Turner & Engle, 1989). However, processing speed was not found to affect mathematical ability. This opposes much literature that explains that processing speed is linked to arithmetic ability in the aging process (Rozencwajg et al., 2010; Salthouse & Coon, 1994).

A higher mathematical ability intuitively would lead one to believe that one's performance in tasks with mathematics would be higher. Surprisingly, our results show that stronger mathematical ability leads users to predict a lower perceived performance, when scored in a questionnaire. While this does not align with the literature presented, it does align with Daniel Kahneman's ideas in which the "system 2", the analytical function of the brain which processes challenging tasks associated with increased mental effort, is also tied with negative emotions such as suspicion and vigilance (2011). This can lead individuals to rate themselves poorly when faced with effortful tasks, even when capable. Our results consistently show that the online grocery shopping experience has more to do with perception and feeling rather than actual performance. It would be pertinent to further explore influences of feelings and attitudes, such as mathematical anxiety and perceptions of cognitive abilities.

It was previously explained that research showed that high self-efficacy scores – in other words, a high belief that a person will achieve their goals – led individuals to overestimate their performance (Schreder et al., 2013). Our results found that in the online grocery shopping context, younger adults did show higher self-efficacy scores than older adults. However, despite rating themselves as more confident in their abilities to successfully maximize their grocery budgets, they did not perform significantly better than older adults. Self-efficacy is found to motivate users to make greater efforts in their tasks (Tams, 2022). While older adults' performance has been similar to younger adults in the context of this study, their self-efficacy scores are significantly lower than younger adults. This is consistent with results on older adults' self-efficacy for internet use and technology in general (Cjaza et al., 2006). This is important, as their confidence in their ability to successfully shop for groceries online has been previously reported to increase their efforts in successfully completing their online tasks (Tams, 2022). Finally, self-efficacy appears to strengthen the link between mathematical ability and perceived online grocery shopping performance. Therefore, if one has poor self-efficacy, high mathematical ability will further decrease perceived performance on online grocery shopping tasks.

2.5.3 Theoretical Contributions

This study added to the available research on older adults and online grocery shopping, where literature is still relatively limited. Specifically, the impact of mathematical ability and natural cognitive changes in aging on the online grocery shopping experience has not often been studied. This study revealed that when considering age in an online grocery shopping context, users who have the most mathematical ability perceived their performance to be worse and vice versa. This interesting result may be due to a variety of factors, such as potential mathematical anxiety and should be further explored. Working memory capacity has also been found to further impact the experience of online grocery shopping much more significantly than users' processing speed, suggesting that this variable may be more significant in the online grocery shopping context.

2.5.4 Managerial Implications

It is known that online shopping that is difficult to use impacts a consumer's probability to use the platform and that online grocery shopping is known to be particularly difficult to use (Freeman, 2009). When a website or an online grocery shopping platform is complex, it makes it difficult for users to reach their goals. Being able to have a consistent, easy to use platform where it is as simple as possible to reach performance goals is key.

Several recommendations have been offered by authors in supporting older adults in their learning, adoption and regular use of technologies in general, which are linked to results from this study. For instance, Jones and Bayen (1998) recommend "break[ing] up instruction into small units with specific goals and relat[ing] new information to older adults' existing knowledge" (in Haeggens, 2012). Since older adults' online grocery shopping experience is particularly linked to working memory capacity, segmenting tasks into smaller ones would be helpful, such as the visualization of quantities of a weighted product or comparisons of other similar offerings. The authors also recommend acquainting older users with help features (Jones and Bayen in Haeggens, 2012), which not all online grocery websites have. This would also be helpful when implementing ideas which may be new to older adults, such as shopping from an event list (ex. “Recommended foods for the Holidays”) or more common difficulties such as scheduling deliveries online. Finally, Gorski (2005) asks for equitable access to technologies for older adults. This aligns with both the literature and the results of this study, where older adults do not appear to be as involved in ideation sessions and usability testing as younger adults are (Haire & Miller, 2020).

This study highlights the need for clearer visual and mental representations in order to reduce the strain on working memory capacity. As previously discussed, new stimuli, such as online grocery platforms and the way their information is displayed, must be treated and understood before the information is crystallized and stored in one’s long-term memory. One way of reducing this strain is by automating processes (Pak et al., 2016). In other words, offering users visual and mental representations on screen (for example by offering quantity/price estimators for bulk foods, or showing visuals of the size of a bag of produce) and allowing recovery from potential mistakes, would make the interface simpler for older users as well as younger users (Pak et al., 2016).

2.5.5 Limitations

While the Digit Symbol Substitution Task (DSST) is a classic pencil and paper cognitive task known to assess an individual’s processing speed, the person’s motor function is also inadvertently tested, due to older adults’ natural decrease in motor rapidity (Ebaid & Crewther, 2020). This is a limitation of this study, as results may have inadvertently captured both changes in cognitive ability and motor rapidity. While it is difficult to isolate processing speed, running this test on the computer may be a consideration for future studies.

Additionally, most participants were active users of the Internet and of technology in general. This was not controlled when recruiting participants, due to the difficulty of recruiting older participants without an external recruitment firm. However, it may not reflect the reality of the average older adult, especially those in their seventies and above. The level of education was also not controlled, which may have impacted the mathematical ability scores obtained. Thus, this may be a sampling error as it is not representative of the overall population if there is an overrepresentation of highly educated individuals who are active users of technologies.

Participants were presented with a single context, which was to maximize the amount of food they can purchase with a given budget. However, this is unlikely to be a reality for all users, but was kept this way in order to be able to more readily standardize and interpret results. Next, participants were asked to select quantities of 1 item per selection, which is not a realistic scenario, but was purposefully done in order to be able to have only 1 correct answer to analyze performance results. It would be pertinent to recreate a more realistic scenario with multiple food selections (e.g. grocery list) for a given budget. According to Freeman (2009), a portion of the complexity of online grocery shopping pertains to the multiple options of a same item, substitutions of items when out of stock or at a high price point or multiple options of a same item.

Next, this researcher met with many participants in their home environment. While this increases external validity as well as ecological validity, it does reduce internal validity. Further testing in a controlled environment may thus be pertinent.

Additionally, this study did not run tests on an actual online grocery shopping website and thus could not replicate an authentic online grocery shopping experience. This was a conscious choice, to remove the influence of branding and attitude towards grocers, among others, in order to focus on the numerical information presented on an online grocery shopping page. This would be remedied by doing further tests on actual online grocery shopping platforms.

Finally, due to the dataset needing to be condensed due to repeated measures, there is a loss of statistical power while analyzing the research model. Additionally, there were 32 participants, which is a low number of participants, particularly if we wish to generalize the results. Further studies with larger sample sizes would help with this limitation and increase the power of the statistical tests when results are analyzed.

2.6. Conclusion

In an aging society that is steadily becoming more digital, online grocery shopping has and continues to experience growth since its introduction to the market. The global Covid-19 pandemic accelerated online grocery shopping use for many, when it was necessary to continue to purchase essential goods such as food in a context that minimized person-to-person contact. The goal of this thesis was to examine the interplay of users of different ages and their interactions with online grocery shopping.

Specifically, the aim of this study was to better understand how and under what conditions aging affects online grocery shopping performance. This study concentrated on numerical information and mental calculations, which are frequent during an online grocery shopping experience. While mathematical ability and changes in one's working memory capacity appeared to impact the online grocery shopping experience, this should not be the case. A website should be usable and accessible to all age groups, all abilities and streamline the page to quickly show essential information. Those with lesser mathematical ability feel they struggle more and we must consider that older adults already face significantly more barriers in obtaining goods and using technologies than younger adults. If perceived performance is impacted by both mathematical ability and low self-efficacy, how can we boost users' confidence in their performance to effectively reach their own performance markers, whether they be saving money or obtaining the exact quantity of foods for a recipe? Would some uncertainty in information provided by simplifiers such as estimators provide enough advantages to increase users' confidence to use online grocery platforms more frequently?

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3. Article 2

Grappling with grocery shopping online: are older users disadvantaged in their experience?

Maya Saric, Constantinos Coursaris, Stefan Tams
Tech3Lab, HEC Montréal, Montréal, Canada

Abstract

We live in a world that is both becoming increasingly digital and whose global population is aging, with older adults living longer and the proportion of older adults steadily increasing. With natural changes in aging come natural age-related cognitive changes, which increase cognitive load. In tandem, daily essentials such as online grocery shopping become more difficult with age. The purpose of this study is to understand how and in what ways age affects online grocery shopping performance. Our results found that age was found to negatively impact cognitive load. Additionally, cognitive load was found to negatively impact performance on online grocery shopping tasks, and online shopping self-efficacy proved to moderate the aforementioned relationship. Theoretical and managerial implications are explored.

Keywords: online grocery shopping, aging, user experience, cognitive load, self-efficacy, arithmetic complexity

3.1 Introduction

We live in a world where the percentage of adults 60 and over is estimated to nearly double from 2015 to 2050 (WHO, 2021), where life expectancy in a country such as Canada is showing continued upwards trends (Public Health Agency of Canada, 2021). Canada alone had over 7 million older adults in 2021 and this number continues to rise (Statistics Canada, 2023).

Natural cognitive changes take place when aging. Among others, older adults' time taken to process new information is longer and their ability to retain and manipulate new information is lesser than for younger adults (Rozencwajg et al., 2010; University of California San Francisco, n.d.). These factors make it more likely that older adults' cognitive load will be exerted than younger adults, when presented with novel online tasks (Granholm et al., 1996).

Jointly, for users of all ages, there is a clear need to be able to quickly and easily obtain daily goods such as groceries. Older adults face additional hurdles in obtaining these essentials, such as challenges with transportation (Huang et al., 2012), reduced mobility (Huang et al., 2012) and worry of the pandemic (Palmer et al., 2021). However, while online grocery shopping was not commonly used by older adults prior to the pandemic, (Gavin, 2020 in Kovalenko, 2020; International Food Information Council Foundation, 2018), the pandemic has fuelled demand for online shopping (Lebow, 2021), including online grocery shopping (Goldman, 2021; Yuen, 2023). Predictably, younger adults have been using online shopping more than older adults, but this generational gap is lessening with time (Garcia, 2018). Also, older adults who have tried shopping online for groceries during the pandemic are more likely to continue using online grocery shopping afterwards (Shen, Namdarpour & Lin, 2022).

However, while older adults appear to be curious about shopping for groceries online, they face more challenges in doing so than younger adults. For instance, older adults take longer to complete their online grocery orders (Sjölinder, Hook & Nilsson, 2000) and it takes them significantly more time in using the interfaces before they feel comfortable with the process of ordering groceries online (Haire & Miller, 2020).

Older adults have different design needs than many younger adults (Kane, 2019), though many digital platforms, such as online grocery shopping, do not always take into account older adults' specific needs. Older adults also appear to be less consulted by interface designers during the implementation of the interfaces, even when trends show that there is an interest (Haire & Miller, 2020). All in all, older adults face more challenges than many younger adults in using online grocery shopping platforms (Haire & Miller, 2020).

Incidentally, for both younger and older adults, shopping for groceries online has been shown to be more challenging than other types of online purchases due to its arithmetic complexity (Desrochers et al., 2015; Desrochers et al., 2019). There is a gap in the literature with regards to understanding how aging affects online grocery shopping performance, particularly when considering the impact of arithmetic complexity (Desrochers et al., 2015; Desrochers et al., 2019).

Older adults are documented to have an increased cognitive load using digital interfaces compared to younger adults and arithmetic complexity adds additional difficulty to online grocery shopping as compared to other types of online shopping (Desrochers et al., 2015), while online grocery adoption is on the rise (Yuen, 2023). Additionally, older adults have used technologies such as online grocery shopping less frequently than younger adults, leading to a lower digital self-efficacy (Czaja et al., 2006). Therefore, we propose the following research question:

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

3.2 Literature Review and Hypotheses

3.2.1 Age and Cognitive Load

When one engages with a very challenging task, their cognitive resources are overexerted (Sweller, 1988). In a moderately challenging but novel task, a person's cognitive resources can be more fully focused on the task at hand and on learning how to organize and solve the problem (Chandler & Sweller, 1991). This process is known as schema development and is common in academic settings, for example (Chandler & Sweller, 1991). An optimal level of difficulty– not too low nor too high– is ideal, in order to stimulate the learner but not overexert them (Van Gerven et al., 2002).

Sweller's Cognitive load theory explains that a limited amount of information can be stored at once in one's working memory (1988). Thus, when a level of cognitive effort is too great, cognitive load is increased, thereby decreasing task performance (Sweller, 1988).

In children and younger adults, individuals are at their peak in absorbing and processing new information (Van Gerven et al., 2002). However, as we get older, natural age-related cognitive changes lead to an increased difficulty in learning new material (Van Gerven, Paas, Van Merrinboer & Schmidt, 2002). However, the way the task and the information is presented leads to an opportunity to either increase or decrease a person's ability to perform in said task, by either increasing or decreasing their cognitive load (Van Gerven, Paas, Van Merrinboer & Schmidt, 2002). Due to older adults' limited processing speed by virtue of natural changes in aging, cognitive load becomes an important factor in information processing. A natural decline in working memory capacity is also found to impact older adults' propensity to increased cognitive load (Granholm et al., 1996).

Given the following theoretical foundations, we propose the following hypotheses to answer our research question:

H1: Age negatively affects cognitive load.

3.2.2 Arithmetic Complexity

Arithmetic complexity refers to the level of difficulty of any calculation (Campbell, 2005). For example, a 1 by 1 digit multiplication, such as 2 x 2 = 4, is considered easier than a two-by-two digit multiplication, such as 52 x 12 = 624, where the latter has multiple steps involved (Bisanz, Sherman, Rasmussen & Ho [pp. 143-162] in Campbell, 2005; Fuson & Kwon, 1992).

Arithmetic development begins in youth as children are introduced to the concept of numbers and counting and continues into young adulthood (Avcil & Artemenko, 2023). Children must be taught to understand mental representation of quantities and "the more complex arithmetic becomes, the more elaborate the mental representations become. There is less reliance on the [real world] and more use of increasingly complex mental schemas, allowing individuals to learn increasingly challenging mathematics" (Fias & Fischer [pp. 43-54] in Campbell, 2005). For example, once a child masters calculations involving integers, the concept of decimals can be introduced (Iuculano & Butterworth, 2011). An accumulation of mathematical knowledge and a peak in higher levels of thinking and reasoning, as well as cognitive abilities required to engage in mathematics, facilitates mastery of mathematics and arithmetic, which naturally increases in children through to young adulthood (Avcil & Artemenko, 2023). Many processes of arithmetic capacity decline with age, when one's cognitive capacities naturally begin to decline (Avcil & Artemenko, 2023).

A simple or low complexity arithmetic calculation becomes automatic and easily retrievable from one's long-term memory (Lemaire & Arnaud, 2008). The tactic required to solve the problem, when also simple and learned young, becomes easily retrievable for both the young and the old (for example, borrowing units when calculating a multi-digit addition) (Lemaire & Arnaud, 2008). Therefore, performance on simple arithmetic tasks is found to be relatively similar among the younger and the older (Lemaire & Arnaud, 2008). However, when the complexity of the arithmetic tasks increases, older adults present more difficulty and a lower performance score than younger adults (Lemaire & Arnaud, 2008; Rozencwajg et al., 2010). Older adults are also less inclined to use as many mathematical problem-solving strategies compared to their younger counterparts (Lemaire & Arnaud, 2008).

A complex mathematical problem requires involvement of fluid intelligence (Primi et al., 2010). Fluid intelligence "refers to mental operations that an individual may use when faced with a relatively novel task that cannot be performed automatically. These mental operations may include forming and recognizing concepts, drawing inferences [and] problem solving" (Flanagan et al., 2000 in Kent, 2017). However, in normal aging, one's fluid intelligence is negatively affected, which particularly impacts older adults' performance in arithmetic problem-solving (Rozencwajg et al., 2010).

Thus, the following hypothesis is proposed involving arithmetic complexity:
H2: Arithmetic complexity positively moderates the relationship between age and cognitive load.

3.2.3 Age & Online Grocery Shopping

In a traditional grocery shopping experience, individuals browse through aisles, being able to pick up foods such as a loaf of bread. In an online grocery shopping experience, an individual browses a virtual bakery aisle, but must access all information on their screens (Benn et al., 2015). Already that the online grocery shopping experience is different, online grocery shopping behavior is not the same for older adults (Lesakova, 2016). They have used online grocery shopping less than younger adults (Bezirgani & Lachapelle, 2021; Hanus, 2016), they spend more time selecting an item (Lesakova, 2016; Sjölinder et al., 2000) and their attitudes towards online grocery shopping appear to be less positive than younger adults, particularly because of their lack of previous exposure to OGS (Bezirgani & Lachapelle, 2021).

Online grocery shopping, as compared to many other types of online shopping such as clothing retail, is considered more complex (Desrochers et al., 2019) and thus more cognitively demanding (Desrochers et al., 2015). There are numerous options of the same product, items are priced per product or per weight, there are considerations in how much product to subtract if the individual has some of the desired foods at home and there are frequent combinable discounts (Desrochers et al., 2019). All of these factors contribute to increasing the arithmetic complexity of the online grocery shopping experience (Desrochers et al., 2019). There also appears to be a general consensus that literature is lacking with regards to older adults and their online grocery shopping experience (Bezirgani & Lachapelle, 2021), particularly when exploring arithmetic complexity (Desrochers et al., 2015).

3.2.4 Age & Task Performance

Task Performance is defined as the degree that users are able to meet task goals (Burton-Jones and Straub 2006). It is understood that aging affects technology task performance (Tams, 2022), though there are few studies focusing on the particularities of age-related changes on technology use (Tams, 2022).

Interestingly, for online grocery shopping, past results have proposed that older adults may perform better than their younger peers, due to their better decision-making skills (Kim & Hasher, 2005). Nevertheless, it is well understood that older adults' overall performance in technology-related tasks is poorer than younger adults, when faced with tasks calling for mental manipulation of numerical information, due to natural cognitive changes in aging (Zeithalm & Fuerst, 1983).

Logically, older adults and younger adults have different goals in grocery shopping (Lesakova, 2016). While younger adults are more inclined to saving time and to focus on convenience due to their increased likelihood of having younger children and families (Morganosky & Cude, 2000), older adults' goals often rest more on saving money and obtaining help with heavier items (Lesakova, 2016). All these factors considered, both populations benefit from a frictionless online grocery shopping user experience (Giroux-Huppé, Sénécal & Léger, 2019). Finally, the presence of frequent numerical information leading to mental calculations, different ways of displaying cost information, among others are a pain point in the OGS experience (Desrochers et al., 2015). As it was previously discussed, arithmetic tasks pose a particular challenge for older adults (Lemaire & Arnaud, 2008; Rozencwajg et al., 2010).

It was previously explained that older adults are more predisposed to elevated levels of cognitive load in tasks while using technologies and that younger adults experience the opposite phenomenon. As a result, we expect the following hypothesis to answer our research question:
H3: There is a negative effect of cognitive load on performance on online grocery shoppingtasks.

3.2.5 Age & Self-Efficacy

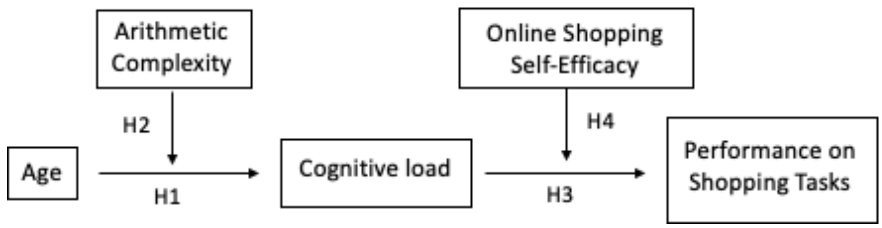
Self-efficacy is defined as a person's "beliefs in his or her capacity to organize and execute behaviors required to produce specific performance attainments" (Bandura, 1977, 1986, 1997). A lower self-efficacy is expected when there is less exposure to technologies, which is the case for older adults (Czaja et al., 2006). Older adults report a lower self-efficacy when confronted with digital tasks, including online shopping, even when they understand these interfaces may be helpful in their routine (Czaja et al., 2006). This is concerning, as a higher perception of self-efficacy is linked to increased motivation in putting in efforts in the task at hand (Tams, 2022). Compellingly, older adults and younger adults with elevated self-efficacy scores have previously demonstrated overestimating their performance (Schreder et al., 2013).

This author has not identified literature focusing on the effects of aging on online grocery shopping task performance, especially when also taking into account online shopping self-efficacy, arithmetic complexity and cognitive load. Given the general literature on technologies and older adults, it appears reasonable that self-efficacy may impact cognitive load and its influence on online grocery shopping performance. Thus, we propose the following final hypothesis:

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

Figure 5 demonstrates the proposed research model to address our research questions.

Figure 5: Research model with proposed hypotheses



3.3 Methodology

3.3.1 Setup

In order to run the study, an IBM (International Business Machines) portable computer with Sensorimotor Motoric Instruments (SMI) eye tracking was employed. The participant's screen was mirrored through TeamViewer, in order for the moderator to control the progression of the tasks. The participant was seated next to the moderator, while they tended to their respective screens.

3.3.2 Experimental Design

Arithmetic complexity is defined as the level of difficulty of any calculation (Campbell, 2005). Factors which increase arithmetic complexity include the way price information is presented, as in weighed rather than the price being presented as an upfront cost, as well as the presence of prices in decimals as opposed to integers.

A reduced factorial design was employed in the context of this study, as part of a within-subjects design. Retaining only the low and the high conditions– either extreme– was intentional, in order to assess the interaction effect between the two variables at their extremes. In this case, this involved arithmetic complexity (price per product or price per weight; integers or decimals). As shown in table 9, two of the conditions (price per weight x decimals & price per product x integers) were retained, as they reflect the extremes of difficulty levels. Therefore, the low arithmetic complexity condition would include integers (e.g. whole numbers) and prices per product (such as 5$ per bag of produce). The high arithmetic complexity condition would include decimals and prices per weight (such as 2.25$/100 g). Results from a pre-test with 8 participants also showed that performance was significantly worse for the high arithmetic complexity condition. Four stimuli were created per condition and conditions were randomized and counterbalanced. Each participant was thus exposed to all conditions. Additionally, age is considered as an experimental selection, due to selecting participants from two age groups, younger adults and older adults.

Table 9, Experimental design

	Price per product	Price per weight

Integers	Low arithmetic complexity Younger, older	N/A
Decimals	N/A	High arithmetic complexity Younger, older

3.3.3 Participants

In total, 32 participants, all residents from Montreal, Quebec, were recruited for the study. Roughly half (17) were younger adults (between 18 and 35 years) and 15 were older adults (60 years or older). 19 of the participants were women and 13 were men. The younger participants ranged from 21 to 32 years of age ($\bar{x} = 26$, $\sigma = 4.50$) and the older participants ranged from 60 to 78 years of age ($\bar{x} = 66$, $\sigma = 6.43$). Age ranges were predefined as 18-35 for young adults and 60 or over for older adults. These age groups were delimited in order to be able to compare the experiences of the younger compared to the older, following the literature on average cognitive peaks and declines in aging.

Multiple methods of recruitment were utilized, ranging from recruitment through the laboratory research panel, by advertising the study at autonomous and semi-autonomous residences and older adult leisure centers, as well as employing snowball sampling through recruited participants. Due to potential restrictions for older adult participants to participate on campus, participants had the option of participating at the HEC Montréal campus or in their home setting.

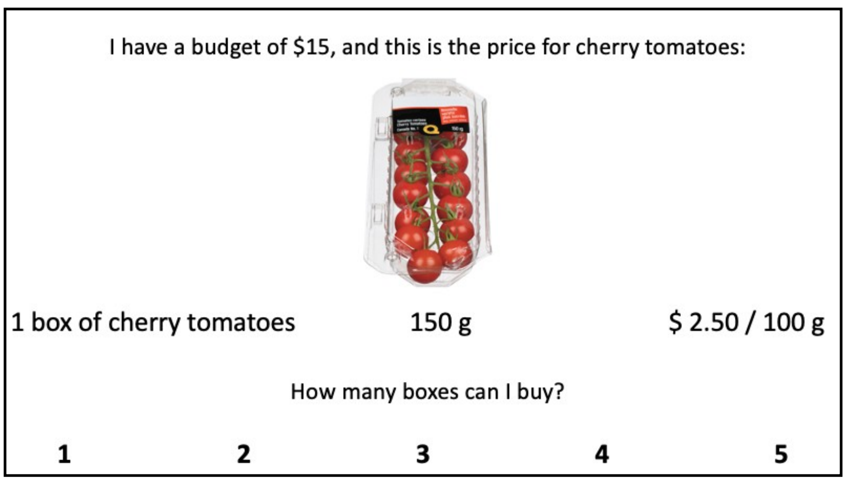
3.3.4 Experimental Task and Stimuli

In order to isolate only the relevant variables being tested, stimuli were created for the purpose of this study, instead of testing an existing online grocery platform. The SMI eye tracker and its corresponding software also functioned best with static elements; thus, the tasks were designed in this way. All stimuli presented are shown in appendix A.

Each stimulus had a white background with large black text and imaging of produce with no visible branding. Each stimulus conveyed to users their budget which in figure 6 is $15, as well as an image of the food they were purchasing. The quantity of food was also included, such as in figure

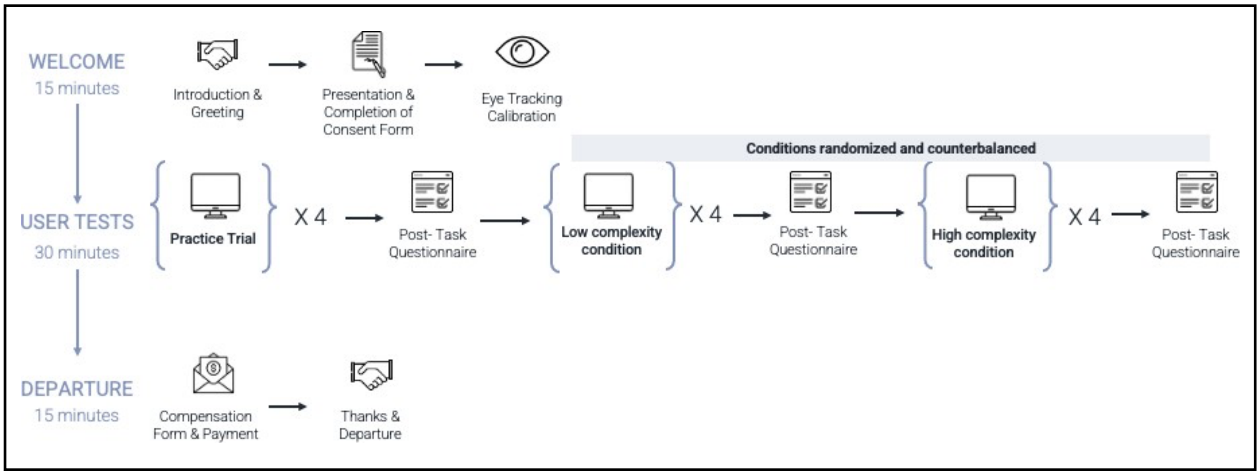
6 being 1 box of cherry tomatoes, the weight which is 400 g in figure 6 and the price information which is $4/100 g in figure 6. Users were tasked to maximize the quantity of food considering their budget. The quantity of food choices was always 1 through to 5, with users being informed that the correct answer always fits within this range. Product weight and cost were roughly inspired from online grocery pricing from Montréal grocery retailers. All numerical information, even when irrelevant to the task, was always presented on the stimulus. For example, the participant would not need the information of the product weight when the price is listed per product. Therefore, the participant must always be aware of how the product price information was being presented for each stimulus, replicating a grocery experience where produce items can be priced per weight or purchased pre-packaged.

Figure 6: An example of a stimulus in the high arithmetic complexity condition



3.3.5 Procedure and Materials

Figure 7: Experimental procedure



In order to facilitate the participation of both older adults and younger adults, participants were allowed the option of partaking in the study from their home or at HEC Montréal campus. This researcher met the participant at their preferred location. If the study took place at HEC Montréal, the laptop and eye-tracker were set up prior to the participant's arrival; otherwise, the instruments were set up while the participant reviewed the consent form. As shown in figure 7, after the consent form was signed, the eye tracker was calibrated. First, there was a pre-experience questionnaire which the user was instructed to complete. The participant was then asked to complete online grocery tasks of which there were two sets, where they were given a budget and instructed to maximize the quantity of food they can purchase considering their budget. There was a practice trial prior to the online grocery shopping tasks, in order for the user to acclimatize themselves to the functioning of the task and to reduce the chance of the results to be affected by a learning effect.

Users were instructed that the answer always ranged between one and five. In order to further optimize the use of the eye tracker, participants were asked to both gaze at their selected answer for several seconds and to state their answer aloud. After each condition, participants were tasked to answer a post-task questionnaire. The order of the conditions was randomized. Finally, the participant filled out the compensation form and was handed $20 cash for their participation in the study. From start to finish, the study lasted approximately one hour and 30 minutes. Qualtrics was used in order to display all questionnaires. Questionnaires are shown in appendix D.

3.3.6 Measures

Qualtrics was used in order to display all questionnaires and the SMI eye tracker was used to obtain eye tracking data.

While either implicit (through tools used in NeuroIS such as eye tracking measures) or explicit (such as self-reported measures, like questionnaires) measures would each provide insightful measures towards the study, combining the two provides richness and nuance to the data and analysis. Explicit measures are helpful in isolating user's choices, opinions and perspectives but are perceptual and only speak to the participant's perceived experience without considering their lived, unconscious experience (de Guinea et al., 2014). Taking both into consideration acknowledges the complexity of the human experience and how implicit measures may affect the explicit ones (de Guinea et al., 2014). It also addresses common method biases which explicit measures alone may provide (de Guinea et al. 2014).

3.3.7 Operationalization of Research Variables

Table 10: Main study constructs and items for objective and subjective measurements

Objective Measurements			
Construct	**Definition**	**Measure**	**Source**
Task Performance	"The degree that users are able to meet task goals" (Burton-Jones and Straub 2006 in Tams, 2022).	Rank	A participant's score compared to the lowest performer, considering both time and accuracy of response.
Cognitive Load	"Level of working memory used during a task" (Sweller, 1988).	Pupil Dilation in mm	SensoMotoric Instruments eye tracker (Teltow, Germany)
Subjective Measurements			
Construct	**Definition**	**Measure**	**Source**
Task Performance	"The degree that users are able to meet task goals" (Burton-Jones and Straub 2006 in Tams, 2022).	Please rate the extent to which you agree or disagree with the following statements: 1. I have completed my assigned task (selecting quantities of food) very effectively. 2. I have performed the task (selecting quantities of food) very well. 3. I have fulfilled the task responsibilities (selecting quantities of food) very effectively.	Questionnaire in Tsai, Chen & Liu, 2007

Self-Efficacy	"A person's belief in their ability to execute behaviors necessary for performance attainment" (Bandura, 1977).	To what extent do you agree or disagree with the following statements: 1. I have the ability to be very good at using online grocery shopping platforms. 2. I have the ability to excel at using online grocery shopping platforms. 3. I have the ability to perform very well when using online grocery shopping platforms.	Questionnaire in Tams, 2022 from Bandura, 2006; Compeau & Higgins, 1995; Marakas et al., 1998
Cognitive Load	"Level of working memory used during a task" (Sweller, 1988).	Please rate the extent to which you agree or disagree with the following statements: 1. The task of selecting appropriate quantities of food took too much time. 2. Selecting appropriate quantities of food required too much effort. 3. Selecting appropriate quantities of food was too complex.	Questionnaire in Pereira, 2000

3.3.7.1 Task Performance

As shown in table 10, task performance was measured objectively through the participant's rank. This measure considers how each participant's performance score compares to the participant who took the longest time to complete each task. It therefore considers both the performance scores of time and of success in percentage and how each participant's rank in their objective score, in comparison to the lowest scoring participant in terms of time (longest time). Success was measured through the percentage of correctly answered results, as all stimuli were created to have a correct answer. A lower rank results in higher performance and a higher rank results in a lower performance. Additionally, perceived performance was measured via a validated questionnaire by Tsai, Chen & Liu (2007). As previously explained, some variables were measured through both implicit and explicit means, in order to provide results of both the lived and perceived experience of the user.

3.3.7.2 Cognitive Load

Cognitive load was previously defined as the level of an individual's cognitive exertion when faced with a novel, challenging task (Chandler & Sweller, 1991). One way cognitive load can be inferred is through the task evoked pupillary response (TEPR) (Hess and Polt, 1964). One's pupils dilate when presented with a difficult task and this "provides a sensitive physiological index of the intensity and online resource demands of numerous cognitive processes [such as] memory retrieval, [or] problem solving [...]" (Reilly et al., 2019). Analysis of the sort is referred to as cognitive pupillometry and is considered to be well documented (Reilly et al., 2019). In fact, arithmetic tasks have been shown to particularly increase pupil dilation (Piquado et al., 2010). However, natural age-related changes impact older adults' pupil dilation (Piquado, Isaacowitz & Wingfield, 2010), making them less sensitive to differences in cognitive load when measured through pupil dilation (Van Gerven et al. in Piquado et al., 2010).

Cognitive load was also measured in both its lived and perceived experience. As such, implicit eye tracking measures were used, as well as a validated questionnaire by Pereira (2000).

3.3.7.3 Self-Efficacy

Since computer and technologies self-efficacy is a stable, situation-specific trait (Thatcher & Perrewé, 2002), a questionnaire was completed by participants prior to beginning the study. A short questionnaire was administered prior to exposure to the online grocery shopping tasks in order to determine each participant's level of self-efficacy with regards to online grocery shopping.

3.4 Data Extraction and Analysis

Eye tracking data was extracted through SensoMotoric Instruments (SMI) BeGaze, while the SMI Experiment Center software was used to input the stimuli. All results were analyzed in SAS Studio. Descriptive statistics, correlation analyses and repeated measures multivariate regressions (ANOVAs) were employed in order to analyze the model's effects.

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 (questionnaire answers and performance scores).

3.5 Results

3.5.1 Global descriptive statistics

For the analysis, datasets were condensed to 64. This choice was made in order to retain richness of data for the cognitive load and performance scores, which had 512 observations, but to reduce variability due to the presence of repeated measures for the linear regressions. Below are the global descriptive statistics of all of the variables measured in the course of this study.

Table 11: Global descriptive statistics of all variables measured

stats	Age	Self Efficacy	Perceived cognitive load	Pupil Dilation	Subjective performance	Rank
mean	44.875	5.677	2.953	10.503	5.275	47.835
sd	20.766	1.034	1.668	2.241	1.340	19.818
min	21.000	3.333	1.000	2.570	2.000	19.216
max	78.000	7.000	6.700	15.218	7.000	100.000
N	64	64	64	54	64	64

Table 11 shows the global descriptive statistics of all participants. Participants' self-efficacy scores were globally high, with a mean of 5.677/7. Self-reported performance scores were high, with the average participant rating their performance as 5.275/7. There was also a wide distribution in the ranks, with the lowest performer obtaining 100 points and the highest performer obtaining 19.216 points ($\bar{x}$ = 47.835).

Pearson correlations of the variables measured in this study are presented below in table 12, in order to understand if there is a correlation between combinations of the measured variables in order to further enrich the analysis of the results.

Table 12: Pearson correlations of all variables measured

		1	$p-value^1$	2	$p-value^1$	3	$p-value^1$	4	$p-value^1$	5	$p-value^1$	6
1	*Age*	1.0000										
2	*Self-Efficacy*	-0.4500	0.0002	1.0000								
3	*Perceived cognitive load*	-0.1255	0.3231	-0.0135	0.9155	1.0000						
4	*Pupil dilation*	-0.6953	0.0000	0.0842	0.5449	0.2231	0.1048	1.0000				
5	*Subjective performance*	0.1525	0.2291	-0.0453	0.7224	-0.6455	0.0000	-0.2146	0.1191	1.0000		
6	*Rank*	0.1422	0.2624	0.0632	0.6198	0.1417	0.2641	-0.1423	0.3048	-0.2299	0.676	1.0000

1. Bilateral level of significance

Logically, perceived cognitive load scores and self-reported performance scores were found to be negatively correlated (r = -0.64550, p = <0.0001). Age and pupil dilation were also negatively correlated (r = -0.69533, p = <0.0001) which corresponds to the literature on the subject previously discussed in the theoretical overview.

The t-tests in table 13 compare the means and standard deviation values of all variables explored in this study, when looking at high arithmetic complexity as compared to low arithmetic complexity.

Table 13: Descriptive statistics and paired sample t-tests comparing low and high arithmetic complexity

	Low complexity		**High complexity**			**T-tests**		**Results**
	Means	**Std. Dev**	**Means**	**Std. Dev**	N_{obs}	$p-value^1$	**Diff**	
Perceived cognitive load	2.188	1.183	3.719	1.744	32	0.0001	-1.531	Statistically different in low complexity compared to high complexity
Subj performance	5.803	1.122	4.747	1.346	32	0.0002	1.056	Statistically different in low complexity compared to high complexity
Rank	47.898	19.772	47.773	20.180	32	0.9764	0.125	Comparable in low complexity and high complexity

Pupil dilation	10.294	2.470	10.713	2.011	27	0.1306	-0.419	Comparable in low complexity and high complexity

1. Bilateral level of significance

When comparing the low and high arithmetic complexity conditions, self-reported performance scores were stronger in the low complexity condition than in the high complexity condition (p = 0.0002). The rank measurement of performance was similar in both conditions ($\bar{x}$ high complexity = 47.77; $\bar{x}$ low complexity = 47.90; p = 0.125). Cognitive load scores were also higher in the high complexity condition when compared to low complexity (perceived cognitive load p = 0.0001), except when considering pupil dilation, where scores were similar across both conditions ($\bar{x}$ high complexity = 10.713 mm; $\bar{x}$ low complexity = 10.294 mm; p = 0.1306)

The descriptive statistics in table 14 compare the means and standard deviation values of all variables explored in this study, when looking at younger adults compared to older adults.

Table 14: Descriptive statistics and independent sample t-tests comparing younger participants and older participants

	Younger					*Older*						*Results*
	mean	**sd**	**min**	**max**	**N**	**mean**	**sd**	**min**	**max**	**N**	$p-value$[1]	
Self-Efficacy	6.059	0.689	5	7	34	5.244	1.190	3.333333	7	30	0.0121	Significant
Perceived cognitive load	3.118	1.726	1	6.700	34	2.767	1.607	1	6.000	30	0.3749	Not significant
Pupil dilation	11.911	1.523	9.928	15.218	30	8.743	1.683	2.570	10.658	24	0.0001	Significant
Subj performance	5.056	1.409	2	7	34	5.523	1.233	2	7	30	0.1796	Not significant
Rank	44.860	22.101	19.216	100	34	51.207	16.589	21.304	89.357	30	0.0415	Significant

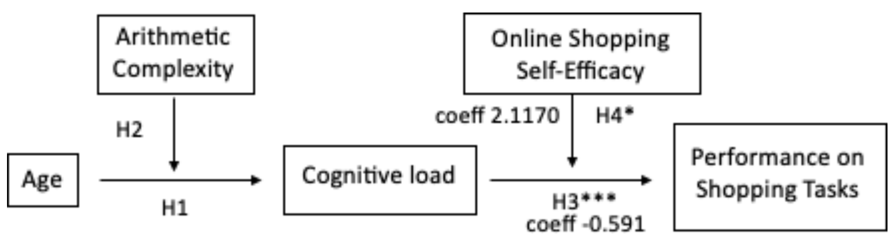
1. Bilateral level of significance

Self-efficacy is statistically higher for younger adults ($\bar{x}$ = 6.06) than for older adults ($\bar{x}$ = 5.24; p = 0.0121). Perceived cognitive load is higher for younger adults (μ = 6.06) than for older adults ($\bar{x}$ = 5.24; p = 0.3749), albeit it is not statistically significant. There are observed trends when they are considered together. Younger adults ($\bar{x}$ = 11.91 mm) have a greater pupil dilation than older adults ($\bar{x}$ = 8.74 mm; $p = 0.0001$) and this result is statistically significant. Both younger adults ($\bar{x}$ = 5.056/7) and older adults ($\bar{x}$ = 5.52/7; $p = 0.1796$) expressed confidence in their level of self-reported performance, though older adults expressed a slightly higher level of self-reported performance. This result is not statistically significant. Younger adults had a better performance score ($\bar{x}$ = 44.86), when measured via rank, than older adults ($\bar{x}$ = 51.21; $p = 0.0415$), though this result is not statistically significant. It can be understood that overall performance, when measured in rank, is comparable for younger adults and older adults.

3.5.2 Linear regressions

Linear regressions were employed in order to test the relationships in this model, controlling for non-independence within observations, due to the presence of repeated measures. Figure 8 shows the supported and unsupported hypotheses. As mentioned in the methodology, multiple measures were obtained for the research variables. Specifically, cognitive load was assessed from two perspectives: its objective manifestation through eye tracking measurements and its subjective experience through self-reported cognitive load. Figure 8 illustrates the data with the most robust support. Full tables are shown in appendix F. All variations of variables in support and not in support are also shown in appendix E.

Figure 8: Research model with supported hypotheses



Notes:
* ≤ 0.1
** ≤ 0.01
*** ≤ 0.001

Figure 8 depicts the results also shown in table 15, which will be presented below. Please note that all p-values are divided by two, as directionality was stated in advance.

Table 15: Linear regressions of research hypotheses

Hypothesis	coefficient	s.e.	T-value	p-value	Result
H1: Direct positive effect of age on cognitive load (Pupil Dilation)	-0.07808	0.01443	-5.41	0.00005	*Not supported*
H2: Moderation of arithmetic complexity on the relationship between age on cognitive load (Perceived cognitive load)	0.004160	0.005128	0.81	0.2118	*Not supported*

H3: Direct negative effect of cognitive load (perceivedcognitive load) on performance (subjective performance)	-0.5609	0.06739	-8.32	0.00005	*Supported*
H4: Moderation of self-efficacy on the relationship between cognitive load (perceived cognitive load) and performance (rank)	2.1170	1.5509	1.36	0.0912	*Marginally supported*

Age was found to have a highly significant negative effect on a user's cognitive load (r^2 = -0.08; p = 0.00005) (H1 unsupported). Therefore, it can be understood that for every additional year of age, the pupil dilation reduces by 0.078 mm when faced with a cognitively demanding task. Cognitive load did differ among younger adults and older adults and this was demonstrated by the latter's significantly elevated task-evoked pupillary dilation (TEPR) (p = 0.0001). As a reminder, an elevated pupil dilation during tasks is an indicator of increased cognitive load (Reilly et al., 2019).

Arithmetic complexity did not show to moderate the relationship between age and cognitive load, whether the latter was measured objectively (pupil dilation) or subjectively (perceived cognitive load) (H2 unsupported, r^2 = 0.004; p = 0.2118). However, there were noteworthy observations when comparing conditions with low and high arithmetic complexity.

In general, task performance scores exhibited a significant decline in high complexity conditions. For instance, the average perceived performance score for the high complexity task was 5.803/7, whereas it was 4.747/7 for the low complexity task (p = 0.0002). Moreover, cognitive load measurements were notably higher in the high complexity condition compared to the low complexity condition. For instance, participants reported an average cognitive effort rating of 3.7 out of 7 for the high complexity condition, in contrast to an average rating of 2.19 out of 7 for the low complexity condition (p = 0.0002).

When it comes to direct effects of cognitive load on performance scores, the hypothesis shows strong support (H3 supported, r^2 = -0.5609; p = 0.00005). When a user scored a task as 1 point more cognitively demanding, they also scored perceived performance ratings as 0.56 points lower. Finally, when it comes to the moderation of self-efficacy on the relationship between cognitive load and performance, the hypothesis is marginally supported (H4 marginally supported, r^2 = 2.1170; p = 0.0912). In other words, self-efficacy strengthened the relationship between cognitive load and performance. Therefore, a higher self-efficacy score strengthens the link between cognitive load and performance, so that when one's cognitive load is low, performance is increased with an improved self-efficacy.

Nonetheless, when examining descriptive statistics and t-tests, it becomes evident that younger adults exhibit notably higher self-efficacy scores ($\bar{x}$ = 6.059 out of 7 and a σ = 0.689) compared to their older counterparts ($\bar{x}$ = 5.244 out of 7 and σ = 1.190). This difference holds statistical significance (p = 0.0121). Put differently, self-efficacy appears to exert some influence on the effect between cognitive load and online grocery shopping performance. Moreover, there is some indication that self-efficacy plays a role in the connection between cognitive load and task performance.

3.6 Discussion

3.6.1 Results Overview

This study shows that age negatively impacts cognitive load. Since this effect is negative, hypothesis 1 is unsupported. Arithmetic complexity does not appear to moderate this relationship, which means there is no support for hypothesis 2. However, cognitive load is a strong indicator of online grocery shopping performance. This is indicative of support for hypothesis 3. Interestingly, performance did not differ substantially between younger adults and older adults. Instead, both younger and older users noticed when the task was more challenging, notably when there were more mental calculations to perform to complete the task (i.e., a higher arithmetic complexity) and reported feeling less confident in their performance outcomes. While older adults showed to have significantly lower self-efficacy scores than younger adults, the effect of self-efficacy on task performance is more subtle. There is some evidence that self-efficacy may moderate the relationship between cognitive load and task performance. Thus, there is marginal support for hypothesis 4.

3.6.2 Discussion

The results in this paper show a negative effect between age and cognitive load– that increased age leads to lesser cognitive load and vice versa. This goes in direct opposition to the phenomenon documenting that older adults are more sensitive in the rate their cognitive capacities are overloaded when exposed to new information (Van Gerven et al., 2002; Granholm et al., 1996). Additionally, on the contrary, older adults also had similar performance on online grocery shopping tasks. However, it was made clear that elevated levels of cognitive load during an online grocery shopping experience impacts online grocery shopping performance. This aligns with Sweller's Cognitive Load theory, in which the psychologist explains that when much of one's limited mental capacities are used, cognitive load increases, thereby decreasing performance in a given task (Sweller, 1988). In this study's context which is realistic to many, users were tasked to maximize their budget with the largest quantity of food. Therefore, their performance was seeking out the best value for their money in terms of quantity. Of course, this is only one context out of many, where another shopper may instead have enough income for food, but whose markers of a successful shopping experience are ones such as quality of foods purchased. However, the fact that one isolated context already significantly impacts performance attests to the need to further explore the scope of an entire online grocery shopping experience. Ultimately, the fact that there are so many considerations when shopping for groceries online make it so that it is one of the more stressful online shopping experiences (Freeman, 2009; Giroux-Huppé, Sénécal & Léger, 2019).

Touching on grocery shopping– including online grocery shopping– being a more stressful experience, it is also understood to be more challenging in terms of its arithmetic complexity. This was demonstrated by users having substantially better performance scores when comparing tasks with more complex mental calculations (e.g. price per weight, decimals) as opposed to less complex mental calculations (e.g. price per unit, integers). This is consistent with the findings of Desrochers et al. (2015), where users had to purchase enough foods for a recipe when comparing prepackaged foods or bulk foods and calculating the appropriate amount required. It can thus be understood that part of the reason why online grocery shopping is more cognitively demanding is its arithmetic complexity.

Users were found to accurately predict their cognitive load and their performance in their shopping experience. They have a feeling when they are not performing well and consistently report higher cognitive load when they perform more poorly. Their perceived experience and their lived experience align well in this respect, and users appear to understand that when a task feels more effortful, their performance decreases. In other words, users appear to predict their performance based on their perceived cognitive effort. In tandem, self-efficacy was lower in older adults in the context of online grocery shopping. This is consistent with the literature on older adults' self-efficacy with technologies in general (ex., Czaja et al., 2006). Based on our results, self-efficacy appears to somewhat strengthen the relationship between cognitive load and online grocery shopping performance.

3.6.3 Theoretical Implications

This study provided contributions to the available research on online grocery shopping experience by adding to the literature on the experience of older adults in online grocery shopping user experience. In particular, the impact of aging, arithmetic complexity and cognitive load on the online grocery shopping experience has not often been studied. This research showed a direct effect of cognitive load and online grocery shopping experience and the moderation of self-efficacy, enriched with both psychophysiological data (e.g. lived experience) and self-reported data (e.g. perceived experience). This allowed for multiple measurements of the same variable and demonstrated the strength of these particular effects in the context of online grocery shopping.

3.6.4 Managerial Implications

Finally, there are considerations for managerial implications. Notably, the way numerical information is displayed on an online grocery shopping platform impacts users' cognitive load as well as their grocery shopping performance. A system with potential for poor performance can lead to users obtaining a different quantity of foods than they expected, seeing a different cost than anticipated in their grocery cart, among others, all of which are factors which may lead to users abandoning their cart.

This study's results hint to a consideration of streamlining information on a page and reducing the number of mental calculations required of the user. This can be done, for example, by displaying clear visual cues, particularly when considering bulk items (for example, a small cup of scooped peanut butter in a container in bulk clearly showing what a 1 cup container looks like). When a user has a mental representation of numerical information, it may simplify their mental representation of what the weight looks like and thus reduce cognitive load and increase their likelihood to purchase the quantity they desire. Estimators are another proposition to reduce cognitive load, where the user can type in a certain amount of grams of deli meats, for example, to obtain an estimation of the slices of salami. This again gives users a mental model of how much food they are purchasing and how much it may cost.

It is to be considered how some information uncertainty may impact the user's online grocery shopping experience. Put differently, it would be pertinent to consider if the convenience benefits of estimators outweigh their downsides, such as a slight lack of accuracy of price or product quantity estimations. In order to simplify a platform, certain tradeoffs must sometimes be made and these may improve its usability and accessibility. User testing to better understand user preferences and attitudes are pertinent when considering adjustments to an online grocery website.

3.6.5 Limitations

This study is not without its limitations. Most participants were very active users of the Internet and technologies in general. While this trend is more likely to be true for younger adults who grew up with these technologies, it is not necessarily reflective of older adults in general, in particular those beyond their sixties. All users also had one context – which is to maximize the number of foods with a specific budget. This is unlikely to be a context that is relevant to all users, but it was done in order to standardize results. This study also had users select quantities of 1 item per selection, which is not necessarily realistic, though it is easier to analyze. This was purposeful in order to see initial trends in a very controlled environment. However, it would be interesting to further analyze mental calculations involved in selecting multiple items in one grocery list. Freeman (2009) mentions that part of the complexity of online grocery shopping involves the multiple options of a same item, substitutions of items when out of stock or at a high price point or multiple options of a same item (for example, almonds can be smoked, salted, prepackaged, bulk, etc.).

It must be considered that this study involved this researcher to meet participants in their home environment, which impacted the pupil dilation measurement due to the different lighting in each home. Pupils are known to dilate or constrict due to both changes in lighting (a natural reflex), as well as a reaction to a complex stimulus, due to its increased cognitive effort (Mathôt, 2018). Therefore, it can be implied that some of the variation in pupil dilation would be attributed to variations of cognitive effort and others would be influenced by the ambient lighting. Furthermore, natural biological changes in the eye as one ages also impacts pupil dilation (Van Gerven et al. in Piquado, Isaacowitz & Wingfield, 2010). Due to this limitation, self-reported measures (e.g. questionnaires) were also employed. Meeting participants in their home setting also increases external validity as well as ecological validity, but does reduce internal validity. Further testing in a controlled environment may also be pertinent for this reason.

Next, this task's conditions were not using an actual online grocery shopping platform and thus did not replicate an authentic online grocery shopping experience. However, this was purposefully done, in order to remove the influence of branding, colors, attitudes towards certain grocers, among others, in order to focus on the numerical information presented on an online shopping page. This would be remedied by doing further tests on actual online grocery shopping platforms.

Finally, due to the dataset needing to be condensed due to repeated measures, there is a loss of statistical power while analyzing the research model. Additionally, there were 32 participants, which is a low number of participants, particularly if we wish to generalize the results. Further studies with larger sample sizes would help with this limitation and increase the power of the statistical tests when results are analyzed.

3.7 Conclusion

We live in an aging society that is concurrently becoming increasingly digital and online shopping has increased steadily since its introduction to the market. Online grocery shopping is no exception and in particular since the advent of the Covid-19 pandemic, increasing amounts of individuals are relying on online grocery platforms to obtain food. This thesis wished to further explore the interplay of different aged users and their interactions with online grocery shopping platforms. Specifically, the aim of this study was to better understand how, why and under what conditions aging affects online grocery shopping performance. This study focused specifically on numerical information and mental calculations, since these are common during an online grocery shopping experience.

Ultimately, the way information is presented on the page has an impact on users' performance, whether they are younger or older. In a world that is becoming increasingly digital, many facets of the online experience warrant consideration and further analysis when it impacts the user's experience. As the worldwide population ages, additional exploration on the particularities of older adults' needs on an online grocery shopping experience is pertinent. Other venues of research may involve attention and focus involved in older adults' online grocery shopping experience. Particularly when faced with multiple stimuli, it may be apt to consider this variable when exploring the influence of multiple numerical stimuli on an online grocery shopping website.

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4. Conclusion

4.1 Research Context, Research Question and Main Results

An aging population combined with the context of increasing global use of online grocery shopping led to an interesting context to explore how age affects online grocery shopping performance. Our research question involved understanding how and in what conditions age impacts online grocery shopping performance. Our results showed that while older adults have decreased working memory capacity and processing speed compared to younger adults, only working memory capacity impacts mathematical ability, required for mental calculations. Mathematical ability was similar among younger and older adults. Self-efficacy is consistently lower in older adults compared to younger adults. Self-efficacy also strengthened the relationship between mathematical ability and shopping task performance, also acting as a moderator in the effect between cognitive load and task performance. Cognitive load is a strong indicator of online grocery shopping performance. While performance did not differ substantially between younger and older adults, users in general perceived when a task was more cognitively effortful through an arithmetically complex task, and rated their performance lower as a result.

4.2 Theoretical and Managerial Contributions

4.2.1 Theoretical Contributions

This research demonstrates that with regard to online grocery shopping tasks, there is a particularly strong direct effect of cognitive load on task performance. Users understand when a task is cognitively challenging and they score their performance as significantly lower when this is the case. Despite being self-aware of more challenging tasks, working memory capacity, which one cannot control, affects mathematical ability required for mental calculations found in online grocery shopping tasks. Therefore, it appears that working memory capacity may play a larger role in the online grocery shopping user experience than processing speed.

4.2.2 Managerial Implications

This study shows that stimuli presenting more numerically challenging (i.e. arithmetically complex) information both increased users' cognitive load and decreased their performance in online grocery shopping tasks. This was the case for both younger and older participants. Therefore, simplifying how information is presented on an online grocery website can result in decreased cognitive load and in an increased ability for shoppers to reach their performance goals, such as saving money, which may encourage them to continue purchasing groceries online. Cognitive effort is increased if users struggle in predicting the total cost or misunderstand the quantities they are purchasing, particularly if it is difficult to mentally visualize the quantities. Being able to anticipate and predict what is in their cart, how much it costs and how much there is of each of it, when combining multiple items, must be as clear as possible. Authors recommend fragmenting the task in order to have multiple smaller tasks to simplify the experience (Jones and Bayen, 1998 in Haeggens, 2012). One way this can be done is by offering clear visuals to represent food quantities (ex. One small container of peanuts, medium and large next to an image of an easily recognizable household item for reference) or with estimators (ex. Slices of salami and cost).

4.3 Limitations and Future Research

As with any research, this study has its limitations. Firstly, the sample size is small at 32 participants. Next, lighting was not standardized as participants were allowed to participate in their home environment, which has an impact on pupillometry measures in eye tracking. Further, the sampling was often snowballed and a high portion of the participants, both younger and older, were both very educated and familiar with digital technologies, which is not representative of the larger population. The stimulus was also a static element as opposed to a true online grocery shopping experience. Finally, the study used one context– calculating the most food they can purchase with their budget– which is not each person's goal in shopping for groceries online. A more dynamic or adaptive context involving other realistic scenarios such as purchasing missing quantities of ingredients for a shopping list or a recipe may be more applicable to others.

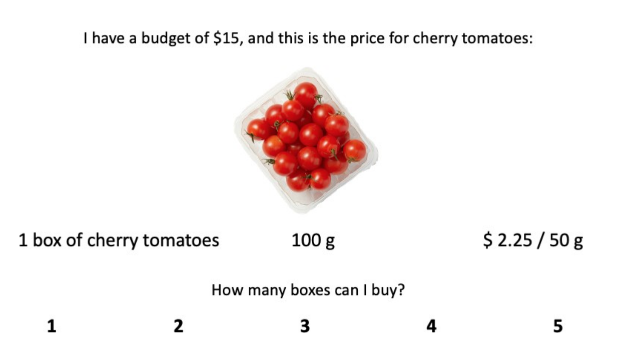
As this study only includes static elements, future research in an authentic online grocery shopping platform would be relevant. Additionally, since working memory capacity had an impact on the online grocery shopping experience, it would be helpful to see if segmenting a task into smaller ones (e.g. by adding estimators or visual representations of quantities) would help improve online grocery shopping performance. Since our results often showed similar task performance among younger adults and older adults, this may also be interesting to study for other consumer groups.

5. Appendices

A. Experimental conditions for low arithmetic complexity and high arithmetic complexity

I have a budget of $15, and this is the price for oranges:  1 bag of oranges 4 lbs $ 3 How many bags can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 1 for low arithmetic complexity condition**
I have a budget of $40, and this is the price for oranges:  1 box of oranges 20 lbs $ 10 How many boxes can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 2 for low arithmetic complexity condition**
I have a budget of $5, and this is the price for oranges:  1 orange 0.31 lb $ 1 How many oranges can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 3 for low arithmetic complexity condition**

I have a budget of $15, and this is the price for oranges:  1 bag of oranges 8 lbs $ 5 How many bags can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 4 for low arithmetic complexity condition**
I have a budget of $15, and this is the price for cherry tomatoes:  1 box of cherry tomatoes 150 g $ 2.50 / 100 g How many boxes can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 1 for high arithmetic complexity condition**
I have a budget of $30, and this is the price for cherry tomatoes:  1 box of cherry tomatoes 750 g $ 1.25 / 100 g How many boxes can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 2 for high arithmetic complexity condition**
I have a budget of $25, and this is the price for cherry tomatoes:  1 box of cherry tomatoes 700 g $ 1.50 / 100 g How many boxes can I buy? **1 2 3 4 5**	**Experimental stimulus for trial 3 for high arithmetic complexity condition**



Experimental stimulus for trial 4 for high arithmetic complexity condition

B. Paper 1 Questionnaires

Self-Efficacy

To what extent do you agree with the following statements:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree or disagree	Somewhat agree	Agree	Strongly agree
I have the ability to be very good at using online shopping platforms.	○	○	○	○	○	○	○
I have the ability to excel at using online shopping platforms.	○	○	○	○	○	○	○
I have the ability to perform very well when using online shopping platforms.	○	○	○	○	○	○	○

Task Performance

Please rate the extent to which you agree or disagree with the following questions:

	Extremely disagree	Moderately disagree	Somewhat disagree	Neutral	Somewhat agree	Moderately agree	Extremely agree
I have completed my assigned task (selecting quantities of food) very effectively.	○	○	○	○	○	○	○
I have performed the task (selecting quantities of food) very well.	○	○	○	○	○	○	○
I have fulfilled the task responsibilities (selecting quantities of food) very effectively.	○	○	○	○	○	○	○

C. Paper 1 Model 0 values

Relations	**coeff**	**P-value**	**Interpretation**
Direct effect of Age on Mathematical Ability	0.231	0.7545	Not supported
Direct effect of Working Memory Capacity on Subjective Performance	0.0025	0.0779	Supported
Direct effect of Processing Speed on Subjective Performance	-0.0211	0.1183	Not supported

D. Paper 2 Questionnaires

Self-Efficacy

To what extent do you agree with the following statements:

I have the ability to be very good at using online shopping platforms.	Strongly disagree ○	Disagree ○	Somewhat disagree ○	Neither agree or disagree ○	Somewhat agree ○	Agree ○	Strongly agree ○
I have the ability to excel at using online shopping platforms.	Strongly disagree ○	Disagree ○	Somewhat disagree ○	Neither agree or disagree ○	Somewhat agree ○	Agree ○	Strongly agree ○
I have the ability to perform very well when using online shopping platforms.	Strongly disagree ○	Disagree ○	Somewhat disagree ○	Neither agree or disagree ○	Somewhat agree ○	Agree ○	Strongly agree ○

Task Performance

Please rate the extent to which you agree or disagree with the following questions:

I have completed my assigned task (selecting quantities of food) very effectively.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○
I have performed the task (selecting quantities of food) very well.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○
I have fulfilled the task responsibilities (selecting quantities of food) very effectively.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○

Cognitive Load

Please rate the extent to which you agree or disagree with the following questions:

The task of selecting appropriate quantities of food took too much time.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○
Selecting appropriate quantities of food required too much effort.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○
Selecting appropriate quantities of food was too complex.	Extremely disagree ○	Moderately disagree ○	Somewhat disagree ○	Neutral ○	Somewhat agree ○	Moderately agree ○	Extremely agree ○

E. Paper 2 Variables in support or not in support of each hypothesis

Hypothesis Number	Hypothesis	Result	Variables in support	Variables not in support
H1	Direct negative effect of age on cognitive load	Not supported	-	Pupil dilation, Perceived cognitive load
H2	Moderation of arithmetic complexity on the relationship between age and cognitive load	Not supported	-	Pupil dilation, perceived cognitive load
H3	Direct negative effect of cognitive load on performance	Supported	Perceived cognitive load and subjective performance	Pupil dilation and rank
H4	Moderation of self-efficacy on the relationship between cognitive load and performance	Marginally supported	Perceived cognitive load and rank	Pupil dilation and subjective performance, Pupil dilation and rank, Perceived cognitive load on subjective performance

F. Paper 2 Complete results table

Hypothesis	coefficient	s.e.	T-value	p-value	Result
H1: Direct negative effect of age on cognitive load (Pupil Dilation)	-0.07808	0.01443	-5.41	<0.00005	*Not supported*
H1: Direct negative effect of age on cognitive load (Perceived cognitive load)	-0.01008	0.01025	-0.98	0.1667	*Not supported*
H2: Moderation of arithmetic complexity on the relationship between age on cognitive load (Pupil Dilation)	0.003149	0.004568	0.69	0.24845	*Not supported*
H2: Moderation of arithmetic complexity on the relationship between age on cognitive load (Perceived cognitive load)	0.004160	0.005128	0.81	0.2118	*Not supported*
H3: Direct negative effect of cognitive load (pupil dilation) on performance (Subjective performance)	-0.1371	0.08835	-1.55	0.06645	*Marginally supported*
H3: Direct negative effect of cognitive load (pupil dilation) on performance (rank)	-1.2267	1.3223	-0.93	0.18105	*Not supported*
H3: Direct negative effect of cognitive load (perceived cognitive load) on performance (subjective performance)	-0.5609	0.06739	-8.32	<0.00005	*Supported*
H3: Direct negative effect of cognitive load (perceived cognitive load) on performance (rank)	2.4313	1.3936	1.74	0.0455	*Supported*
H4: Moderation of self-efficacy on the relationship between cognitive load (pupil dilation) and performance (Subjective performance)	0.03955	0.1330	0.30	0.3843	*Not supported*
H4: Moderation of self-efficacy on the relationship between cognitive load (pupil dilation) and performance (rank)	0.3220	2.0048	0.16	0.43685	*Not supported*

H4: Moderation of self-efficacy on the relationship between cognitive load (perceived cognitive load) and performance (subjective performance)	0.01277	0.07816	0.16	0.43565	*Not supported*
H4: Moderation of self-efficacy on the relationship between cognitive load (perceived cognitive load) and performance (rank)	2.1170	1.5509	1.36	0.0912	*Marginally supported*

G. Article accepted to the SIGHCI Pre-ICIS workshop

Saric, M. S., Tams, S. & Coursaris, C. K. (2023). Grappling with Online Grocery Shopping: An Age-related study. Proceedings of the Twenty-second Annual Pre-International Conference on Information Systems HCI Workshop in MIS Research (pre-ICIS), December 10, Hyderabad, India

H. Ethics review forms

HEC MONTRÉAL

Comité d'éthique de la recherche

Le 13 juillet 2022

À l'attention de :
Constantinos K. Coursaris
HEC Montréal

Objet : Approbation éthique de votre projet de recherche

 # Projet : 2023-5016

Titre du projet de recherche : Personnes âgées, arithmétique mentale et épiceries en ligne

Source de financement : R1234 - R2188A - R2106 - R2882

Titre de la subvention : NSERC-Prompt Industrial Research Chair in User Experience

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Votre projet de recherche a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains par le CER de HEC Montréal.

Un certificat d'approbation éthique qui atteste de la conformité de votre projet de recherche à la *Politique relative à l'éthique de la recherche avec des êtres humains* de HEC Montréal est émis en date du 13 juillet 2022. Prenez note que ce certificat est **valide jusqu'au 01 juillet 2023.**

Dans le contexte actuel de la pandémie de COVID-19, vous devez vous assurer de respecter les directives émises par le gouvernement du Québec, le gouvernement du Canada et celles de HEC Montréal en vigueur durant l'état d'urgence sanitaire.

Vous devrez obtenir le renouvellement de votre approbation éthique avant l'expiration de ce certificat à l'aide du formulaire *F7 - Renouvellement annuel*. Un rappel automatique vous sera envoyé par courriel quelques semaines avant l'échéance de votre certificat.

Lorsque votre projet est terminé, vous devrez remplir le formulaire *F9 - Fin de projet (ou F9a - Fin de projet étudiant sous l'égide d'un autre chercheur)*, selon le cas. **Les étudiants doivent remplir un formulaire F9 afin de recevoir l'attestation d'approbation éthique nécessaire au dépôt de leur thèse/mémoire/projet supervisé.**

Si des modifications sont apportées à votre projet, vous devrez remplir le formulaire *F8 - Modification de projet* et obtenir l'approbation du CER avant de mettre en oeuvre ces modifications.

Notez qu'en vertu de la *Politique relative à l'éthique de la recherche avec des êtres humains de HEC Montréal*, il est de la responsabilité des chercheurs d'assurer que leurs projets de recherche conservent une approbation éthique pour toute la durée des travaux de recherche et d'informer le CER de la fin de ceux-ci. De plus, toutes modifications significatives du projet doivent être transmises au CER avant leurs applications.

Vous pouvez dès maintenant procéder à la collecte de données pour laquelle vous avez obtenu ce certificat.

Nous vous souhaitons bon succès dans la réalisation de votre recherche.

Le CER de HEC Montréal

HEC MONTRĒAL

Comité d'éthique de la recherche

CERTIFICAT D'APPROBATION ÉTHIQUE

La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains et qu'il satisfait aux exigences de notre politique en cette matière.

Projet # : 2023-5016

Titre du projet de recherche : Personnes âgées, arithmétique mentale et épiceries en ligne

Chercheur principal :
Constantinos K. Coursaris,
Professeur agrégé, Département de T. I.,HEC Montréal

Cochercheurs :
Maya Saric; Stefan Tams; Salima Tazi; David Brieugne; Pierre-Majorique Léger; Sylvain Sénécal

Date d'approbation du projet : 13 juillet 2022

Date d'entrée en vigueur du certificat : 13 juillet 2022

Date d'échéance du certificat : 01 juillet 2023

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2022-07-14 à 16:10

HEC MONTRÉAL

Comité d'éthique de la recherche

Le 27 juin 2023

À l'attention de : Constantinos K. Coursaris, Professeur agrégé

Projet # 2023-5016

Titre : Personnes âgées, arithmétique mentale et épiceries en ligne

Source de financement : PROMPT + Chaire institutionelle (R2185; R2188A; R2106; R2882)

Bonjour,

Pour donner suite à votre demande de renouvellement, le certificat d'approbation éthique pour le présent projet a été renouvelé en date du 01 juillet 2023. **Ce certificat est valide jusqu'au 01 juillet 2024.**

Vous devez donc, avant cette date, obtenir le renouvellement de votre approbation éthique à l'aide du formulaire *F7 - Renouvellement annuel.* Un rappel automatique vous sera envoyé par courriel quelques semaines avant l'échéance de votre certificat.

Lorsque votre projet est terminé, vous devrez remplir le formulaire *F9 - Fin de projet (ou F9a - Fin de projet étudiant sous l'égide d'un autre chercheur)*, selon le cas. **Les étudiants doivent remplir un formulaire F9 afin de recevoir l'attestation d'approbation éthique nécessaire au dépôt de leur thèse/mémoire/projet supervisé.**

Si des modifications sont apportées à votre projet, vous devrez remplir le formulaire *F8 - Modification de projet* et obtenir l'approbation du CER avant de mettre en oeuvre ces modifications.

Prenez également note que tout nouveau membre de votre équipe de recherche devra signer le formulaire d'engagement de confidentialité et que celui-ci devra nous être transmis lors de votre demande de renouvellement.

Nous vous souhaitons bon succès dans la poursuite de votre recherche.

Cordialement,

Le CER de HEC Montréal

HEC MONTRĒAL

Comité d'éthique de la recherche

RENOUVELLEMENT DE L'APPROBATION ÉTHIQUE

La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet d'une évaluation en matière d'éthique de la recherche avec des êtres humains et qu'il satisfait aux exigences de notre politique en cette matière.

Projet # : 2023-5016

Titre du projet de recherche : Personnes âgées, arithmétique mentale et épiceries en ligne

Chercheur principal : Constantinos K. Coursaris, Professeur agrégé, Département de T. I.

Cochercheurs : Maya Saric; Stefan Tams; Salima Tazi; David Brieugne; Pierre-Majorique Léger; Sylvain Sénécal

Date d'approbation du projet : 13 juillet 2022

Date d'entrée en vigueur du certificat : 01 juillet 2023

Date d'échéance du certificat : 01 juillet 2024

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2023-06-29 à 11:19

HEC MONTRÉAL

Comité d'éthique de la recherche

ATTESTATION D'APPROBATION ÉTHIQUE COMPLÉTÉE

La présente atteste que le projet de recherche décrit ci-dessous a fait l'objet des approbations en matière d'éthique de la recherche avec des êtres humains nécessaires selon les exigences de HEC Montréal.

La période de validité du certificat d'approbation éthique émis pour ce projet est maintenant terminée. Si vous devez reprendre contact avec les participants ou reprendre une collecte de données pour ce projet, la certification éthique doit être réactivée préalablement. Vous devez alors prendre contact avec le secrétariat du CER de HEC Montréal.

Projet # : 2023-5016 - 318 - golden girls

Titre du projet de recherche : Grappling with grocery shopping online: are older users disadvantaged in their experience?

Chercheur principal : Constantinos K. Coursaris, Professeur agrégé, HEC Montréal

Cochercheurs : Maya Saric; Stefan Tams; Salima Tazi; David Brieugne; Pierre-Majorique Léger; Sylvain Sénécal

Date d'approbation initiale du projet : 13 juillet 2022

Date de fermeture de l'approbation éthique : 17 novembre 2023

Maurice Lemelin
Président
CER de HEC Montréal

Signé le 2023-11-17 à 15:26

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Retrait d’une ou des pages pouvant contenir des renseignements personnels

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