Cognitive Limitations of Older E-Commerce Customers in Product Comparison Tasks

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Abstract. The number of older consumers making e-commerce purchasing decisions is constantly rising. We examined the impact of age-related cognitive limitations on older adults' choices in a series of multi-attribute choice tasks designed to mimic the process of products comparison and selection on e-commerce platforms. 135 older, middle-aged and younger adults were asked to participate in an on-line experiment. We found significant age-related limitations in solving simple and moderately difficult tasks, especially in the older adults group. The mediational model indicated an interplay between the age-related limitation and the role of additional variables (Helplessness of Contracting an Infectious Disease and Numeracy) in explaining the relationship between aging and performance in the multi-attribute choice task.
Keywords: aging; multi-attribute choice; helplessness; numeracy; e-commerce

1 Introduction

Since the pandemic, older adults are confined at home, and the value of their e-commerce purchases (which was high even before the pandemic's onset) is expected to rise. This is also due to the aging oxf population in all developed countries in the world. Monetary considerations aside, older consumers become increasingly dependent on e-commerce platforms because of their enforced isolation. The Internet becomes one of the main platforms for social interaction for older adults - luckily, according to the Pew Research Institute study, in 2019 73% of US citizens aged over 65 were connected to the Internet [26]. However, this raises the question - how well are current e-commerce web sites adapted to requirements of older adults?

While the user interfaces of e-commerce web sites are usually adapted for older consumers [22], these are mainly superficial changes, affecting such aspects as navigation and readability. The underlying mechanics of product comparison, recommendation, and purchasing decision support is the same for older and younger consumers. This situation has been recognized as harmful by HCI researchers, who appealed against conflating aging with accessibility [16]. In this article we consider the question - do cognitive limitations due to aging affect consumer choices significantly? If the answer to this question turns out to be positive, then the underlying recommendation mechanisms of e-commerce will have to be modified to adapt to older consumers. We seek an answer to our research question by the means of an experiment that uses a decision task similar to the ubiquitous function of product comparison in e-commerce systems.

The experiment setup and data uses methodology from psychology to investigate the effects of age and age-related cognitive limitations on the performance of participants in product comparison tasks.

2 Related Work

2.1 Older adults, e-commerce, multi-attribute choice

Research on the use of e-commerce systems by older adults is focused mostly on two interconnected areas: accessibility and acceptance [18, 17, 23]. Deeper adaptation of existing e-commerce systems to the needs and limitations of older adults has only recently been considered. El Shamy et al. [8] proposed an experiment to measure the impact of recommender systems and comparison matrices on older adults' e-commerce decisions' quality, but no final results have been published yet. Pawłowska et al.[24] used multi-agent simulation to verify the existence of harmful feedback loop in typical recommendation algorithms, if used by older adults with cognitive limitations. Von Helversen et al. [13] studied the influence of on-line reviews on purchasing decisions of older adults and revealed statistically significant differences in how older and younger people respond to negative reviews. It is important to note that such consideration of the needs, preferences, and abilities of older adults in the context of e-commerce systems is beneficial to all of its users, not only to the older population [7].

2.2 Age-related cognitive and motivational changes

A vast array of research findings indicate gradual decline in basic fluid cognitive abilities such as processing speed of information and working memory capacity throughout adult life span [9, 28, 31]. Therefore, maintaining high level of performance in cognitively demanding tasks may require much effort. In response, related compensatory mechanisms may arise, with older adults conserving their limited cognitive resources by simplifying interactions with the environment, both in terms of the quantity and complexity of the attended information [1, 14].

In line with the idea that costs for searching and storing information increase due to age-related cognitive decline, which in turn leads to a decrease in intrinsic motivation [14], older adults put less value on informational gain and more on achieving a satisfactory decision outcome. While younger adults are often quite likely to be systematic and use maximizing decision strategies, older adults often search for information only for as long as it is sufficient [6]. Both age-related decline in cognitive resources and motivational changes may contribute to the reduction in information search among older adults.

Emotion regulation, helplessness and anxiety of contracting an infectious disease, and numeracy. Besides cognitive and motivational factors, emotion regulation and numeracy are important parts of decision-making competence [3]. A number of both financial and health-related decisions require making choices between alternatives that are characterized by numerous attributes. Therefore, in the current multi-attribute choice study we have used Subjective [10] and Objective Numeracy [19] measures to assess

numerical skills of the participants, because numerical abilities are important for calculating various attribute weights and values for several alternatives. Individuals highly confident about their mathematical competences may use the emotions that result from analyzing numerical information to make better decisions. On the other hand, less confident individuals are directed by emotions that are irrelevant for effective decision making [25]. In the context of the COVID-19 pandemic, we also included our own measures of helplessness and anxiety of contracting an infectious disease as additional scales that may indicate the dysfunctional role of a high level of maladaptive emotions when making rational choices. The Scale of Helplessness of Contracting an Infectious Disease was inspired by the Intellectual Helplessness Scale initially developed for the education setting, where one tries to solve a task without understanding it for a prolonged period of time and a lack of control ultimately leads to intellectual helplessness in the domain related to that task [27]. Similarly, emotions that accompany the uncontrollable situation of the pandemic may lead to the feelings of helplessness and anxiety, and overshadow rational choices. Our previous research indicate that intellectual helplessness toward math is a strong predictor of low achievement in math [2]. Additionally, anxiety toward math was highly correlated with intellectual helplessness toward math, but only intellectual helplessness (not anxiety) was a significant predictor of low math achievement [30].

2.3 Strategies in multi-attribute choice tasks

Despite the fact that the value of older adults' e-commerce purchases is most likely going to rise, the age-related limitations in performance of decision making tasks and in particular multi-attribute choice tasks, seem to be quite stable and universal. Numerous research has indicated that older adults perform worse than younger adults in cognitively demanding experimental decision making tasks. It is especially evident for the multi-attribute choice tasks that demand the use of a more complex strategy requiring thorough information processing [20, 21]. Weighted Additive (WADD) is an information-intensive strategy, which involves multiplication of cue values by cue validities and addition of them for each alternative. The alternative with the largest sum is being selected. This strategy allows for compensation, where two cues favoring one alternative can counterbalance other cue favoring another alternative. Another, yet simpler, compensatory strategy is TALLY [11], where cue weights are ignored and cue values are added for each alternative. Again, the alternative with the largest sum is the one that is being selected.

Take The Best (TTB) is the simplest of the strategies considered here, it is a strategy based on one, most important information. That means making decision by looking at the cue with the highest validity and its respective values. If the most predictive cue (one with the highest validity) is not discriminative, then TTB involves looking at the cue with the second-highest validity and so on.

Older adults have difficulty applying decision rules that are necessary for selection of an alternative from a set of choices [15]. In multi-attribute choice tasks older adults have considerable problems with learning value of cues [5] and options [29].

Following previous work, we formulate the hypothesis of a significant age-related decrease in the performance of multi-attribute choice task. Moreover, we test new hy-

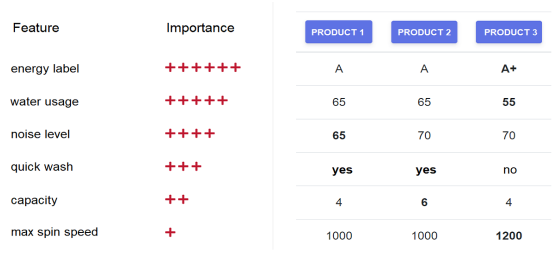

Fig. 1. Experiment screen showing the single multi-attribute choice task. On the left are the washing machine features and their importance expressed as a number of plus signs. On the right are the 3 products and their features.

potheses that numeracy and the Scales of Helplessness and Anxiety of Contracting an Infectious Disease may be significant predictors of decision making performance.

3 Experiment Design

The design of our experiment aimed at replicating the product comparison function which is ubiquitous in e-commerce platforms. In order to investigate our research question, we needed an objective ground truth - a best choice in each product comparison. This was achieved by instructing experiment participants to select the best washing machine out of 3 available products taking into account multiple features of varying importance. The importance of each feature was specified in the experiment using a simple metaphor - a number of plus signs associated with each feature, ranging from 1 (least important) to 6 (most important). Participants had to repeat the product comparison task 32 times.

Figure 1 shows the main screen of a single experiment task. The experiment interface was designed to resemble feature comparison table available on many e-commerce platforms where users can select a number of product for comparison, which then are displayed in a tabular form.

3.1 Participants

One hundred thirty five people participated in the study, including 49 younger adults (26 women; age range 20-30; mean age = 25.65, SD = 2.96; mean years of education = 14.76, SD = 2.45), 45 middle-age adults (24 women; age range 42-52; mean age = 46.38, SD = 3.02; mean years of education = 14.98, SD = 2.55) and 41 older adults (23 women; age range 65-76; mean age = 69.27, SD = 3.00; mean years of education = 15.41, SD = 2.94). Participation in the study took between 1 and 2 hours, participants were remunerated for their participation. The study was approved by the Ethics Committee of the SWPS University of Social Sciences and Humanities in Warsaw.

3.2 Materials

Measures of Helplessness and Anxiety of Contracting an Infectious Disease, and Numeracy. Participants completed the Scales of Helplessness and Anxiety of Contracting an Infectious Disease (Rydzewska Sedek, in preparation). Each of these scales was

composed of ten items with answers on a 5-point Likert Scale ranging from 1 = “never” to 5 = “always”. An exemplary item from the Scale of Helplessness was ”I feel helpless in the face of the possibility of contracting an infectious disease” and a sample from the Scale of Anxiety was ”I am concerned when someone around me sneezes without covering their mouth”. The reliabilities of these scales were impressively high: Cronbach’s alpha = .92 and Cronbach’s alpha = .93, respectively for the Scale of Helplessness and the Scale of Anxiety of Contracting an Infectious Disease.

Finally, participants also completed Scales of Subjective Numeracy [10] and Objective Numeracy [19]. Scale of Subjective Numeracy consisted of seven questions measuring subjective view on cognitive abilities in relation to fractions and percentages, and preferences for displaying numeric information. The Objective Numeracy Scale was comprised of three open-ended questions measuring numerical skills and an additional warm-up question. The reliability of the Subjective Numeracy Scale was satisfactory (Cronbach’s alpha = .83), the reliability of the Objective Numeracy Scale was also satisfactory considering it is a 3-item only scale (Cronbach’s alpha = .65).

Product comparison in multi-attribute choice tasks. On the screens preceding the task, participants were given a brief description of the meaning of each feature and its relative importance for an average consumer expressed as a number of plus signs, ranging from 1 plus sign for the least important feature (max spin speed) to 6 for the most important one (energy label). The participants were explicitly instructed to follow the preferences of an average consumer. On the left side of the screen depicted on the Figure 1 the list of features is presented in a descending importance order. On the right side there are 3 washing machines and their feature values. If for a given feature one or two washing machines had a better feature value, for example a lower noise level preferred by most of the customers, the feature value was printed in bold.

We designed 32 task sets of 3 products each. The values of the features were chosen to realistically reflect washing machines currently available on e-commerce platforms, which is new for a multi-attribute choice task (as the values are usually presented as dichotomous yes/no). For 17 of the tasks, marked as ’simple’, washing machine feature values were selected to model a non-compensatory choice. In these tasks, using either a simpler TTB or TALLY strategy, or using the WADD strategy allowed the user to select the same correct answer. The remaining 15 tasks were constructed to model a compensatory choice. 8 compensatory choice tasks were marked as ’moderately difficult’. A user could determine the correct answer using both the TALLY and WADD strategy. In the remaining 7 tasks, marked as a ’difficult’, only the WADD strategy allowed to choose the correct answer.

3.3 Experiment Procedure

The experiment was conducted online. The participants were redirected from a research participant recruitment agency portal to the experiment website. At the beginning of the study, participants filled out a personal questionnaire. Subsequently, the instruction was displayed to the participants, followed by four training trials for the multi-attribute choice tasks. In each task, the participants were instructed to select the best products guided by the importance of the given feature (number of pluses). Afterwards the participants were informed that the training part has finished, and were directed to the core part of the experiment where they have to solve 32 multi-attribute product choice

Variable	1	2	3	4	5	6	7	8
1. Age	-							
2. Simple	$-.24^{**}$	-						
3. Moderate	-.11	.01	-					
4. Difficult	.04	.12	$.38^{**}$	-				
5. S_Numeracy	-.10	$.25^{**}$	.13	.06	-			
6. O_Numeracy	-.05	$.39^{**}$	$.19^{*}$	.16	$.53^{**}$	-		
7. Helplessness	$.23^{**}$	$-.23^{**}$	$-.17^{*}$	-.13	.01	$-.19^{**}$	-	
8. Anxiety	-.08	-.12	$-.22^{**}$	-.09	-.01	$-.20^{**}$	$.80^{**}$	-

Table 1. Correlation table of dependent and independent variables. Simple = simple decision tasks; Moderate = moderately difficult decision tasks; Difficult = difficult decision tasks; S_Numeracy = Subjective Numeracy Scale; O_Numeracy = Objective Numeracy Scale; Helplessness = Scale of Helplessness of Contracting an Infectious Disease; Anxiety = Scale of Anxiety of Contracting an Infectious Disease. Note: *p $<$ .05, **p $<$ .01.

tasks. There was no feedback regarding the correctness of the chosen answers. Finally, participants filled in the questionnaires listed in the Materials section.

4 Results and Discussion

4.1 Age-related differences in accuracy of multi-attribute choice tasks

In the first part we will describe main results of the effects of age and parameters of tasks on the accuracy of performance. Next, we will overview the correlation matrix of the main variables. Finally, we will demonstrate the role of cognitive and emotional variables as potential mediators and covariates of the relationship between age and multi-attribute decision making task performance.

Proportion of correct decisions. The key measure of performance in the multi-attribute product choice task is the proportion of correct decisions. For the record, the participants did not receive feedback concerning the accuracy of their decision making, except for the training tasks. A 3 x 3 (Age [younger adults, middle-age adults, older adults] x Decision Difficulty [simple, moderately difficult, difficult; within-subject variable]) mixed ANOVA on the proportion of correct decisions yielded one main effect and an interaction effect. Importantly, the assumption of equality of error variances was not violated because Levene's test was not significant across age groups. There was a main and strong effect of decision difficulty, F (2, 264) = 92.22, MSE = .055, p $<$ .001, $\eta_p{}^2$ = .411, with the significant differences (p $<$.001, Sidak post-hoc tests) between all decision tasks – the more difficult was the task, the worse the performance. This main effect was qualified by the significant Age x Decision Difficulty interaction, F (2, 264) = 3.47, MSE = .055, p = .01, $\eta_p{}^2$ = .050. As shown in Figure 2, for the simple decision task the performance of younger adults was significantly higher than of both the middle-age group (p = .005) and the older adults group (p = .006). For the moderately difficult decision task the performance was higher in the middle-age group than in the older adults group (p = .04). There were no significant age differences for the most difficult decision tasks. For decision difficulty comparisons within the age groups, there were significant differences between three levels of difficulty for younger adults (p $<$ .01)

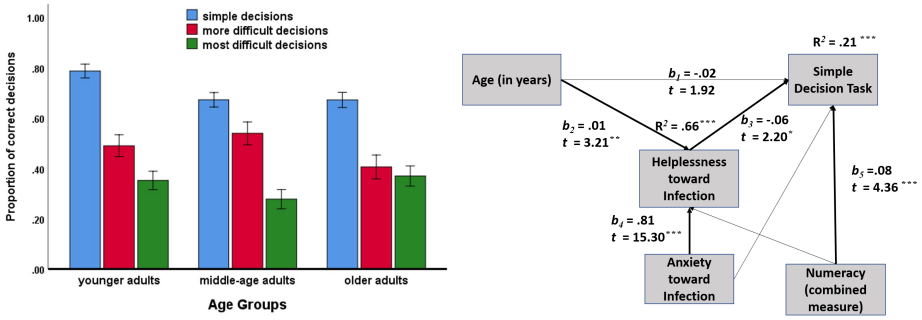

Fig. 2. Performance of decision task as the function of age and decision difficulty and model of the mediational effect of age via the Scale of Contracting an Infectious Disease on simples decision task. Error bars represent the standard errors of the mean. Entries are unstandardized regression coefficients with t-test values. *p $<$ .05, **p $<$ .01, ***p $<$ .001

and middle age adults groups (p $<$ .05). However, for the older adults group there was no significant difference in performance between the moderately difficult and the difficult decisions, but significantly better performance (p $<$ .001) for the simple decision tasks in comparison to the moderately difficult decisions (see Figure 2). The discovered age-related limitations in solving simple and moderately difficult multi-attribute product choice tasks, especially in the older adults group, confirm previous findings [20, 21]. Interestingly, age differences are observed even between younger and middle-age groups in relatively simple tasks. This suggests that problems with learning values of cues and options that were previously demonstrated in older adults [5, 29] could be also identified among the middle-age group.

Mediation analysis for the simple decision task. The correlation table between accuracy of the decisions, age, and questionnaire measures (see Table 1) indicates that age (in years) significantly and negatively correlates with the performance of simple decisions and age positively correlates with the Helplessness Scale. Additionally, numeracy scales, Scales of Helplessness and Anxiety significantly (although not systematically) correlate with accuracy for simple and moderately difficult decision tasks. The results indicating that numeracy is related to the accuracy of decisions in multi-attribute choice task are in line with the previous findings that numeracy is an important predictor of performance in many decision tasks. The significant correlations between objective numeracy and both anxiety and helplessness confirmed the predicted link between low level of numeracy and emotions that are irrelevant for effective decision making [25]. The results showing that feelings of helplessness and anxiety of contracting an infectious disease are significant predictors of accuracy of multi-attribute choice task performance are to our knowledge the novel and original demonstration (specific to the COVID-19 pandemic) of the dysfunctional role of such negative emotions when making rational multi-attribute choice in the domain of e-commerce.

Although the above correlational analyses indicated (in rather indirect way) the important role of numeracy scales and Scales of Helplessness and Anxiety of Contracting an Infectious Disease in explaining the age-related limitation on accurate solving of the

simple decision task, only the Scale of Helplessness of Contracting an Infectious Disease appeared to be the classical mediation variable. Namely, the mediation analysis (applying the Process software) [12] examining the role of Helplessness of Contracting an Infectious Disease (see Figure 2), indicates that aging has significant impact on Helplessness, and Helplessness is a reliable mediator of the relationship between aging and proportion of correct answers in simple decision tasks. We applied 10000 bootstrap samples for estimating percentile bootstrap confidence intervals. To integrate these findings, this model is supplemented by two covariates. Because the responses of the subjective and objective numeracy scales were highly correlated (see Table 1), we created the combined measure of Numeracy (averaging the standardized scores for both subjective and objective numeracy scales). The second covariate was the Scale of Anxiety of Contracting an Infectious Disease. This combined Numeracy scale was a strong, additional predictor of the simple decision accuracy. Even though the Scale of Anxiety was strongly related to the Scale of Helplessness, it did not significantly predict the accuracy of simple decision task.

In sum, the mediational model with covariates nicely integrates the correlational analysis and indicates the interplay between the age-related limitation and the role of additional variables (especially Helplessness and Numeracy) in explaining the relationship between aging and performance in simple multi-attribute decision making task. However, we are aware that this mediational model, although original, is still preliminary and elucidating psychological mechanisms behind the role of intellectual helplessness as a mediator demands further experimental work (e.g., experimental manipulation of the intensity of a mediator, see [4]).

5 Conclusions

In this article, we have considered the question of how cognitive limitations of older consumers affect their choices when using a popular user interface function in e-commerce systems: product comparison.

We have found significant aging effects, especially for moderately difficult decisions, when the proportion of correct decisions of older adults drops as low as 40%. This effect is mediated by feelings of helplessness that are enhanced by the pandemic. This effect can have a severe adverse impact on the training and functioning of recommendation systems. To mitigate this effect, we recommend that content-based recommendation systems should not be used for older adults as these are particularly sensitive to individual choices that may be - as shown in this article - 60% incorrect. Instead, it is better to use collaborative or hybrid recommendation systems, in particular specially designed algorithms that would take into account age diversity.

All these questions will be the subject of our future research. This article is also a call to arms to designers of e-commerce recommendation systems to adapt them for older consumers with cognitive limitations.

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