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Identifying design barriers for older adults in food packaging: A usability study

Identificación de barreras de diseño para adultos mayores en envases de alimentos: Un estudio de usabilidad

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Abstract

Given that human physical and cognitive abilities change as we age, the food packaging industry should respond to the new necessities that emerge. However, ergonomics and universal design principles are frequently absent in the packaging design process, resulting in the implementation of package solutions that can become an obstacle for many users. The purpose of this study was to evaluate the usability of ten food and beverage packages found in the market with two age groups of older adults (65-74 years and 75+ years). Participants' hand-grip strength and lateral pinch strength were measured as background information. We evaluated task efficiency measuring opening and closing times, and identified interaction issues in opening, closing, and pouring liquids. We also explored performance differences between the two group samples by comparing opening and closing times. There was no significant difference between age groups in terms of hand strength.

Usability test results showed similar difficulties and errors during package opening in both groups due to low visibility of interactive components, unclear affordances, and anthropometric incompatibilities. We also observed a frequent use of knives or scissors to open the packaging. We identified some problems to effectively close the packaging and no errors in pouring liquids. The comparison analysis showed a significant difference only in opening times between the two age groups for the thermoformed tray (laminated cheese). Our study can help designers and engineers to introduce usability testing in their design process and to create easy-to-use packaging solutions considering older adults' capabilities and limitations.

Keywords: food packaging; packaging design; older adults; usability

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Resumen

Dado que las capacidades físicas y cognitivas cambian a medida que envejecemos, la industria del envasado de alimentos debería responder a las necesidades que surgen. Sin embargo, la ergonomía y los principios de diseño universal frecuentemente están ausentes en el proceso de diseño de empaques, lo que resulta en la implementación de soluciones que pueden convertirse en un obstáculo para muchos usuarios. El propósito de este estudio fue evaluar la usabilidad de diez envases de alimentos y bebidas encontrados en el mercado con dos grupos etarios de adultos mayores (65-74 años y 75+ años). La fuerza de agarre manual y la fuerza de pellizco lateral de los participantes se midieron como antecedentes. Evaluamos la eficiencia de las tareas midiendo los tiempos de apertura y cierre, e identificamos problemas de interacción en la apertura, cierre y vertido de líquidos. También exploramos las diferencias de desempeño entre las muestras de dos grupos comparando los tiempos de apertura y cierre. No hubo diferencias significativas entre los grupos de edad en términos de fuerza de mano. Los resultados de las pruebas de usabilidad mostraron dificultades y errores similares durante la apertura del paquete en ambos grupos debido a la baja visibilidad de los componentes interactivos, prestaciones poco claras e incompatibilidades antropométricas. También observamos un uso frecuente de cuchillos o tijeras para la apertura. Identificamos problemas para cerrar eficazmente los envases y no hubo errores en el vertido de líquidos. El análisis comparativo mostró una diferencia significativa sólo en los tiempos de apertura entre los dos grupos de edad para la bandeja termoformada (queso laminado). Nuestro estudio puede ayudar a los diseñadores e ingenieros a introducir pruebas de usabilidad en su proceso de diseño y a crear soluciones

de embalaje fáciles de usar teniendo en cuenta las capacidades y limitaciones de los adultos mayores.

Keywords: envases de comida; diseño de envases; personas mayores; usabilidad

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1. Introduction

The global population is changing. It is estimated that by 2050, the proportion of people aged 60 years and older will reach approximately 22% worldwide (World Health Organization, 2021). Since nutrition is essential for healthy aging, older people are becoming an increasingly relevant market segment for the food packaging industry (Bell et al., 2017a).

Food packaging can become a significant obstacle for older adults to get appropriate nutrients (Bell et al., 2016; Clegg & Williams, 2018). To access food or liquids, the most relevant actions are opening, dispensing, and closing the packaging or disposal (International Organization for Standardization [ISO], 2011; Wenk et al., 2016). For older adults, these actions may be challenging due to sensory capacity limitations (e.g., visual acuity, color perception, hearing, and tactile sensitivity) and a decline in dexterity and hand strength (Carse et al., 2010; Czaja et al., 2019; Ford et al., 2016; Wenk et al., 2016), which also vary among

older individuals (Czaja et al., 2019). Thus, designing inclusive packaging should be the norm to provide easy access and use. ISO Standard 11156:2011 states that "The accessible design of packages is a worldwide matter of concern because it allows everybody to use them safely, comfortably, and with satisfaction, irrespective of age, perceptual and cognitive ability, level of physical functioning, language and culture" (ISO, 2011). Nevertheless, ergonomics and universal design principles are commonly absent in food packaging design, which may cause many users difficulties interacting with them along with feelings of vulnerability and dissatisfaction (Bell et al., 2017a; Carse et al., 2010; Ford et al., 2016; Sudbury-Riley, 2014; Świda et al., 2019). Considering users make decisions such as repurchasing, paying more/less, or switching to other products offered in the market based on the problems or benefits they experience at any stage of user-packaging interaction, it is essential for the packaging industry to understand older users' needs, preferences, and expectations (Mumani & Stone, 2018; Świda et al., 2019; Wenk et al., 2016; Winder et al. 2006).

Pousette et al (2014) identified that openability was the most important factor for older adults' satisfaction with packaging. Supporting the relevance of this stage, seminal literature addressing the interactive quality of packaging mainly focuses on the opening process. For instance, there is a group of studies showing how jar openability is influenced by user characteristics (e.g., age, gender, grip strength, and wrist strength) and jar features such as diameter and friction (Rowson & Yoxall, 2011; Yoxall & Janson, 2008; Yoxall et al., 2006; Yoxall et al., 2008; Yoxall et al., 2010). Duizer et al. (2009) found problems with tight lids, lug closures, peelable induction seals, and continuous thread closures. Many participants in their study stated they have required assistance opening packages, especially older adults with upper limb weakness.

The latest studies on packaging opening with older adults have explored diverse solutions available in the market, such as twisting, pulling and pushing opening systems, ripping along indentations, thermoformed trays, and ring pull cans (Wenk et al., 2016); meat peelable packaging (Hensler et al., 2015); and rigid

plastic containers with peelable lids (Canty et al., 2012). Interaction with hospital food packaging has also been studied, given the relevance of nutrition for patient recovery (Bell et al., 2017b; Bell et al., 2016; Bell et al., 2013). In addition, Świda et al. (2019) explored older consumers' needs when handling food packaging through a survey and interviews, finding difficulties such as removing protective films and foil sealings due to lack or ineffective pull-tabs, packaging damage during opening which difficulted the re-close, small tear-tabs, low visibility of opening systems, and high strength required to open PET bottles. Yoxall et al. (2019) found that the main obstacles for package accessibility were related to cognition and false affordances, misconceptions, and low level of packaging intuitiveness. Ford et al. (2016) found issues at the point of sale regarding packaging font sizes, nutritional information, and cooking instructions. Participants had limitations with gross and fine motor skills that affected the opening process, and a necessity of smaller portion sizes, which could be solved by effective resealable packaging.

Overall, previous research suggests that hand force is not the only factor influencing openability and packaging interaction. Other aspects include cognition (Yoxall et al., 2019), dexterity (Bell et al., 2017b; Bell et al., 2016), context (e.g., oily fingers reduce finger-pack friction) (Canty et al., 2012), packaging design (Bell et al., 2017a; Bell et al., 2013; Świda et al., 2019; Yoxall et al., 2019), and individual expectations and previous experiences (Wenk et al., 2016).

Despite the recommendations provided by empirical research, multiple factors affect packaging design, and evidence is limited. Consequently, problematic packaging for older adults can still be found in the market, which suggests that companies in the field may require integrating packaging testing techniques with older adults into their development processes to make a difference. Nevertheless, most studies in the literature use methodologies that require specific measurement equipment, big sample sizes, or significant data collection and analysis time that could hinder its application in practice (e.g., dexterity tests, motion capture, hand strength evaluations, and in-depth interviews).

Pousette et al. (2014) proposed using the usability construct to study user-packaging interaction and understand its physical and cognitive implications. ISO Standard 9241-210 defines usability as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO, 2019). System usability levels depend on different factors, including usefulness, efficiency, effectiveness, learnability, accessibility, and satisfaction" (Rubin & Chanel, 2008). This way, usability studies gather various relevant variables for packaging design, while they are cost-effective due to the use of small sample sizes (Nielsen, 2012a), simple equipment, and data analysis oriented to measure performance indicators and the identification of errors and design barriers (Tullis & Albert, 2013).

Considering the relevance of nutrition for an increasing population of older adults and the variability found in this population in terms of physical and cognitive capacities, the present study aims to identify interaction barriers in a selection of food and beverage packages found in the market with two age groups of older adults through a usability study. To add insights about different stages of packaging interaction, we evaluated three actions: opening, closing, and pouring liquids. Our study can help designers and engineers to introduce usability testing in their design process and to create easy-to-use packaging solutions considering older adults' capabilities and limitations.

2. Materials and Methods

2.1 Selection of Packaging

We selected 10 food and beverage packages with different opening mechanisms. We included one novel packaging (pre-cooked chickpeas) and a novel easy open system (milk box) to study its usability and participants' reactions (Figure 1).

Figure 1: Packaging Selected for the Study.

1.PET bottle with screw cap/Water
2.Beverage carton with twist off cap/Juice
3.Pouch with heat seal/ Powdered soup
4.Jar with plastic seal/Mayonnaise
5.Aluminum can with ring pull tab/Beverage
6.Can with ring pull system/Sauce
7.Beverage carton with easy open lid/Milk
8.Rigid plastic container with peelable foil seal and cardboard cover/Pre-cooked chickpeas
9.Thermoformed tray with peelable lidding film/Laminated Cheese
10.Cellophane roll-wrap with tear tape/Crackers

Note. Product brands are concealed.

Figure 1. Packaging selected for the study.

We developed a descriptive analysis of the intuitive quality of each packaging based on the affordance-based methodology from De la Fuente et al. (2015). The description is focused on the opening action due to the relevance and higher complexity of this interaction. It includes an identification of the sub-tasks required to open each packaging, affordance, and perceptual information (Table 1).

Table 1: Packaging Opening: Affordance Description			
Subtask	Affordance	Design Feature	Possible perceptual Information
Beverage carton with easy open lid/Milk			
Finding place to open	Find-ability	Top end, easy open system	Color (white on light blue background) A yellow sign with red letters signals its location
Grabbing the easy-open system seal	Grip-ability	Easy open system	Tiny plastic connection between the easy-open upper and lower sections. Low visibility due to size and lack of contrast between this component and the rest of the easy open system (all white). Seal is too small for users' fingers to grasp.
Tearing the easy open seal to open the lid	Tear-ability	Easy open system	Tiny plastic connection between the easy-open upper and lower sections
Beverage carton with twist off cap/ Juice			
Finding place to open	Find-ability	Top end, easy open system	Color (red)
Turning the easy-open system to remove the lid	Turn-ability	Easy open system	Red lid
Grabbing the easy open seal	Grip-ability	Easy open interior	Color (white on red background). Small plastic handle. Handle size and free space are small for users' fingers.
Pulling the easy open seal	Pull-ability	Easy open interior	Small plastic handle. Users with reduced finger strength could have difficulties.
Cellophane roll-wrap with tear tape/Crackers			
Finding place to open	Find-ability	Close to one end, perimeter	Visibility is limited due to low contrast between the easy open system (gold) and the background (brown crackers).
Grabbing the easy-open system seal	Grip-ability	Easy open system	Extreme of the golden band. It could be hard to identify the edge of the band, due to small size and low color contrast.
Pulling the easy open seal to open the packaging	Pull-ability	Easy open system	The golden band guides the opening process around the packaging.
Thermoformed tray with peelable lidding film/Laminated Cheese			
Finding place to open	Find-ability	Easy open system	White color sign indicates "re-sealing packaging" with a small size arrow. This sign provides information about the function, but it does not highlight the easy-open system.
Grabbing the easy-open system	Grip-ability	Easy open system	Grabbing the film to separate it from the packaging semi-rigid plastic base may require high visual and touch accuracy, which could cause difficulties for some users.

Pulling the film to open	Pull-ability	Top film	The upper film shape guides the opening action.
Rigid plastic container with peelable foil seal and cardboard cover/Pre-cooked chickpeas			
Finding how to remove the cardboard cover	Find-ability	Cardboard cover	No graphic sign to guide the action.
Removing the cardboard cover	Pull-ability	Cardboard cover	There is no sign advising the right way to remove the cardboard cover. It can be pulled out or teared apart.
Finding how to open the plastic container	Find-ability	Lid	Circular lid
Removing the lid	Turn-ability/Pull-ability	Lid	The circular lid may afford "turning" due to previous experiences with circular lids. The right action to open the lid is to pull it out. There is no surface to position the fingers, though; this could confuse users. There are no graphic signs guiding the opening process.
Finding place to open the aluminum seal	Find-ability	Seal	Grasping zone surpassing the container
Grabbing the grasping zone	Grip-ability	Seal	Grasping zone is the size of users' fingers to aid users.
Pulling the aluminum seal to open the container	Pull-ability	Seal	Seal shape guides the opening action.
PET bottle with screw cap/Water			
Finding place to open the plastic container	Find-ability	Lid	White lid
Turning the lid to remove it	Turn-ability	Lid	Cylindrical shape that can be easily recognized from previous experiences. It could cause difficulties for people with limited strength or dexterity. There is no graphic sign to guide the user in the opening process.
Can with ring pull system/Beverage & Sauce			
Finding place to open the can	Find-ability	Easy open system	The easy open system is not highlighted by color, and there is no graphic information guiding the user. They rely on previous user knowledge (mental model of how these easy open system works).
Grabbing the easy-open system	Grip-ability	Easy open system	There is limited space to position fingers between the pulling system and the can surface
Pulling up the easy open system	Pull-ability	Easy open system	Pulling up the easy open system to break the seal may require a level of strength that not all users have.
Jar with plastic seal/Mayonnaise			
Finding place to open the transparent plastic seal with pre-cuts	Find-ability	Lid	There is low contrast between the pre-cut marks and the transparent seal. This could cause difficulties for people with impaired vision, or in dim light.

Grabbing the seal in the pre-cut area	Grip-ability	Seal easy open system	Small area to be grasped by fingers.
Tearing the seal by the pre-cut marks	Tear-ability	Seal easy open system	Users with limited strength and dexterity could have difficulties in this action.
Finding place to open the jar	Find-ability	Lid	Lid color (black)
Turning the lid to open the jar	Turn-ability	Lid	User mental model. The type of lid is well known.
Pouch with heat seal/ Powdered soup			
Finding place to open the bag	Find-ability	Top end	There are graphic cutting marks with a scissors icon
Cutting the bag with scissors	Cut-ability	Top end	
Note. Description grounded in the affordance-based methodology proposed by De la Fuente et al. (2015).			

Table 1. Packaging opening: Affordance description

2.2 Sample

Since older people are a diverse group in terms of capabilities and limitations, we defined two age groups: group A including adults from 65 to 74 years old and group B with older adults over 75 years. To identify most usability issues, we considered the minimum sample size of 5 participants per group suggested by Rubin and Chisnell (2008). Inclusion criteria for the participants were age (being 65 or more years) and not requiring formal assistance or a caregiver to perform daily activities.

We used a convenience sample of participants recruited in a community center in Chile and some participants known by the research team. Group A included 10 participants (range 66 to 73 years old) and Group B included 7 participants (range 75 to 91 years). Table 2 shows the demographic characteristics of the sample and background information regarding hand health issues.

Table 2: Participants' Demographic Characteristics and Background		
Demographics and Background	Group A	Group B
Sample Size *(n)*	10	7
Age, *M(SD)*	70.2 (2.7)	80.7(5.6)
Gender		
Male *(n)*	3	3
Female *(n)*	7	4
Hand Pain		
Yes *(n)*	5	4
No *(n)*	5	3
Hand Illnesses		
Yes *(n)*	4	2
No *(n)*	6	5

Table 2. Participants' Demographic Characteristics and Background

2.3 Apparatus

The study was conducted in a room where the main activity was the usability test. Most participants were evaluated in a room at a community center catering to older people. Two tests were done in a room outside the community center.

We defined two zones in the testing room. Zone 1 included a table and two chairs to receive the participants and ask preliminary questions. We also performed hand strength evaluations using a hand-grip dynamometer and a lateral pinch gauge Dynatron DM17.

Zone 2 was set on a table. At one side of the table, we placed a surface measuring 56 cm in length and 36 cm in width, and approximately 90 cm from the floor, to allow participants to manipulate the packaging while standing. Two GoPro Hero 5 cameras were attached to the surface (left and right side), pointing at participants' hands. We placed kitchen utensils that participants could need close to this area, such as disposable plates and cups, scissors, a can opener, knives, and forks. Next to this arrangement, we organized the products to be evaluated.

2.4 Procedure

Each participant was evaluated individually. In some cases, couples entered the testing room together and then developed the evaluation independently. Participants were welcomed by the research assistant who explained the study objectives, read the informed consent for them, and asked them to sign it. Next, participants responded to demographic and background questions, which were recorded directly on a computer by the research assistant.

To gather additional background information, we performed a hand-grip and lateral pinch strength test with the participants' dominant hand. Following American Society of Hand Therapists (ASHT) recommendations, we asked the participants to grab the dynamometer with their dominant hand, sit down with their shoulders neutrally rotated and adducted, elbow flexed in 90 degrees, neutral position of the forearm, wrist extension (dorsiflexion) between 15 and 30 degrees and ulnar deviation between 0-15 degrees (MacDermid et al., 2015). They kept the same position to measure a lateral pinch, where the pinch gauge was positioned between the thumb pad and the lateral area of the index finger. To measure hand-grip and lateral pinch strength, participants were asked to perform three attempts pressing the tool at their maximum capacity with a 15-second break between them. We used participants' average values for hand-grip and lateral pinch strength (kilograms/force).

After completing the preliminary evaluation, participants were asked to approach the usability test setting (Zone 2). The packaging order was randomly assigned for each participant to avoid any possible influence of the sequence of products in the evaluation (Budiu, 2021).

At the beginning of the session, the principal investigator explained the procedure and asked them to "think aloud" as much as possible (Nielsen, 2012b). She reminded the participant that the activity was video recorded, and that it was not allowed to provide any help or intervene during the evaluation. The principal investigator read the following instruction to the participants: "Up next, you will

be asked to put or pour some food/liquid content in a plate/glass or open it and close it following researcher directions. Please provide verbal comments about any concerns, difficulties, or positive aspects of the packaging handling. You can use the available utensils as you wish." Later, the principal investigator turned on the cameras and asked the participant to take some food/liquid from the packaging and put it on a plate/glass following the randomized sequence of products (e.g., "please take the milk container and pour some milk on the plastic cup, then close it"; "please, take the cheese container and put a slice on the plate, then close it"). This direction was repeated for each one of the 10 products selected for the study to register the way participants opened the packaging, poured the content, and closed the reusable packaging, depending on the case. Once the test was finished, we thanked the participants for their collaboration and gave them the products they manipulated during the test in a reusable bag.

2.5 Data Analysis

To explore possible differences in hand-grip and pinch strength between the two sample age groups that could influence packaging interaction, we compared strength data using t-Student analysis with independent samples.

For the usability test, we studied participants' performance in both age groups by evaluating their efficiency or "the quickness with which the user's goal can be accomplished accurately and completely" (Rubin & Chisnell, 2008, p. 4) using opening times with all packages and closing times when necessary. We also evaluated effectiveness, or "the extent to which the product behaves in the way that users expect it to and the ease with which users can use it to do what they intend" Rubin & Chisnell, 2008, p. 4). We quantified the number of mistakes participants made during opening and closing tasks and identified the errors and difficulties participants showed during the interaction, including pouring liquids. Errors were defined as any alternative interaction strategy carried out by the participants that was not the way the packaging design indicates.

Finally, we further compared opening and closing times between both age group samples (A and B) in order to explore performance differences. Mean values were compared with the t-Student test for normal distributions. We used the Welch's t test for unequal variances, and the Mann-Whitney-Wilcoxon test for non-normal distributions.

For all statistical analyses, we used R software (R Core Team, 2022) to perform the calculations.

3. Results

3.1 **Hand-grip and Pinch Strength Analysis**

Results of hand-grip and pinch strength are shown in Table 3. T-Student comparison analysis showed no significant difference in hand-grip strength ($t(15)=0.94$, $p=.36$) and lateral pinch strength ($t(15)=-0.58$, $p=.57$) between the two age groups.

Table 3: Sample Hand Strength

	Hand-grip Strength (k/f)		Pinch Strength (k/f)	
Groups	Mean	SD	Mean	SD
Group A (n=10)	20.90	8.54	5.25	1.97
Group B (n=7)	17.39	5.80	5.84	2.26

Note. Measures performed with hand-grip and pinch dynamometers Dynatron DM17

Table 3. Sample Hand Strength

3.2 **Usability Study**

3.2.1 Efficiency and Effectiveness

Table 4 (opening) and 5 (closing) summarize task times by group, along with the maximum number of mistakes made by the participants, and errors and difficulties

found in both groups. One male participant of 91 years old could not open the mayonnaise jar and the can with a ring pull system (sauce) due to pain in his hands.

Table 4: Opening Times by Group and Identification of Errors

Group	n	Minimum Time	Maximum Time	Mean Time	SD	Maximum Number of Errors per participant	Number of participants with errors	Difficulties/Errors made by participants in Group 1 and Group 2
Jar with plastic seal/Mayonnaise								
Group A	10	5	62	19.4	16.87	2	6	Turning the lid without taking out the plastic seal Using a knife or scissors to open the plastic seal
Group B	6[a]	7	27	12.83	7.39	2	4	Difficulties in identifying the pre-cut marks
Aluminum can with ring pull tab / Beverage								
Group A	10	4	21	8	5.5	0	0	No errors found
Group B	7	2	17	6.43	4.93	0	0	Some participants showed difficulties separating the easy-open system from the can
Can with ring pull system / Sauce								
Group A	10	6	38	15.5	9.81	1	5	Using a knife to separate the easy-open pulling system from the can
Group B	6[a]	6	29	15.33	8.62	1	2	Using a knife once the can is open to separate the easy-open lid from the can
Beverage carton with twist-off cap/ Juice								
Group A	10	6	18	9.7	4.24	1	1	Not noticing the interior seal and starting to pour
Group B	7	8	27	14.14	6.74	1	1	Not completely removing the seal Some participants had difficulties pulling out the seal
Beverage carton with easy open lid/ Milk								
Group A	10	2	52	16.9	18.48	2	4	Unfolding the packaging folds (as required in beverage cartons without easy-open) Lifting the lateral sides of the easy-open instead of cutting off the seal at the end
Group B	7	6	34	15.43	10.75	2	4	Using a knife to cut off the seal at the tip of the easy open system Some participants had trouble cutting off the easy open seal Others had problems with milk splattering when they exerted excessive strength during the action
Cellophane roll-wrap with tear tape/Crackers								
Group A	10	6	56	33.1	19.31	4	7	
Group B	7	13	61	31.86	15.31	2	5	Not noticing the easy open system Using knives or scissors to open the packaging Unfolding the extreme folds instead of using the easy open Some participants had trouble grabbing the easy-open system
Thermoformed tray with peelable lidding film/Laminated Cheese								
Group A	10	9	36	20.5	10.46	3	7	Not identifying the easy open system Not being able to separate the plastic cover from the base Trying to open the package from other corners Using a knife to cut the upper plastic film
Group B	7	18	80	38.71	21.47	3	5	Cutting one end of the packaging with scissors Separating the upper plastic film with a knife Some participants had difficulties choosing an opening strategy, taking time to screen the packaging
Rigid plastic container with peelable foil seal and cardboard cover/ Pre-cooked Chickpeas								
Group A	10	20	76	36.1	19.78	2	7	Turning the lid instead of pulling it out Prying with a knife under the lid to open it Tearing the aluminum seal during opening
Group B	7	16	128	59.86	39.04	3	6	Some participants had trouble sliding the cardboard cover, especially in surpassing the extreme point of the curve; they had difficulties exerting enough force to pull out the lid and remove the foil seal
PET bottle with screw cap/Water								
Group A	10	4	18	7.8	4.29	0	0	Participants showed some difficulties in exerting the required force during the opening action
Group B	7	4	8	6.57	1.4	0	0	
Pouch with heat seal/ Powdered soup								
Group A	10	2	30	12.5	10.82	2	3	Opening with their hands Opening with a knife
Group B	7	4	12	7	2.89	2	3	Insufficient opening cut impeded pouring the powdered soup Excessive opening cut We found an extra step in the process: tapping the package against a surface to avoid having powdered soup in the cutting area

[a]The 91-year-old participant could not open the jar due to pain in their hands.

Table 4. Opening Times by Group and Identification of Errors

Table 5: Closing Times by Group and Identification of Errors								
Group	n	Minimum Time	Maximum Time	Mean Time	SD	Maximum Number of Errors	Number of participants with errors	Difficulties/Errors made by participants in Group 1 and Group 2
Jar with plastic seal/Mayonnaise								
Group A	10	1	13	4.8	3.39	1	4	The lid does not fit well with the base, making it hard to turn.
Group B	6	3	11	4.83	3.13	1	4	Closing the lid with the plastic seal on.
Beverage carton with twist off cap/ Juice								
Group A	10	1	6	3.6	1.84	1	2	Putting the seal back
Group B	7	2	8	4.29	2.14	1	3	
Beverage carton with easy open/Milk								
Group A	10	1	6	3.3	1.57	1	1	Not pressing the lid to secure its closure.
Group B	7	1	5	3	1.63	0	0	
Thermoformed tray with peelable lidding film/Laminated Cheese								
Group A	9	1	8	4.11	2.2	0	0	-
Group B	7	1	7	3.71	2.43	1	3	Not pressing the upper film against the base to secure the closure
Rigid plastic container with peelable foil seal and cardboard cover/Pre-cooked chickpeas								
Group A	10	5	13	7.4	2.5	1	3	Not pressing the lid to secure its closure
Group B	7	4	17	10	4.51	1	2	
PET bottle with screw cap/Water								
Group A	10	3	6	4.1	0.99	1	1	Not fitting the lid on the bottleneck on the first try. Action was repeated until they successfully turned it.
Group B	7	4	8	5.14	1.35	1	2	
Pouch with heat seal/ Powder soup								
Group A	10	3	14	6.9	3.28	0	0	-
Group B	7	3	9	5.71	1.89	0	0	-
Note. One participant in Group 1 did not close the thermoformed tray (laminated cheese), and one participant in Group 2 did not close the mayonnaise jar.								

Table 5. Closing Times by Group and Identification of Errors

Figure 2 illustrates participants' opening attempts and the use of utensils. Overall, difficulties and errors were found due to low visibility of interactive components (e.g., location of easy open systems, pre-cut marks), unclear affordances (e.g., unfolding the packaging folds in the carton milk and crackers' cellophane packaging instead of using the easy open system), and anthropometric incompatibilities between the easy open system and finger size (e.g., the carton milk small tab and the tight ring pull in the sauce can, which was difficult to separate with fingers).

Figure 2. Examples of Packaging Opening Attempts

For the pouring action, participants did not show problems or errors. We only identified minimal issues with the beverage carton milk package, which could initially go out with too much strength, but participants managed to control it and perform the action successfully.

As far as the closure of packaging is concerned, we identified some difficulties in fitting the lid on the packaging base and sealing the lid/cover. Participants also mentioned how they would close the reusable packaging that did not include an integrated closing system (e.g., crackers and powdered soup), for instance, by folding the upper side and closing it with an external element such as tape or a rubber band.

Finally, we were able to observe participants' positive disposition to explore the novel packaging selected for the study (pre-cooked chickpeas), despite their difficulties during the interaction and handling time.

3.2.2 Performance Comparison between Group A and Group B

We only found a significant difference between groups in opening times for the thermoformed tray packaging in the laminated cheese ($t(15)= -2.34$, $p=.03$). We did not find significant differences in closing times between Group A and B.

4. Discussion and Conclusions

Although it is known that hand strength declines after age sixty (Czaja et al., 2019; Yoxall et al., 2006), we found no significant difference in hand force between groups (hand-grip and lateral pinch), suggesting that differences in usability issues between groups are not determined by hand strength. In this regard, our study supports the thesis that there are multiple factors influencing older adults' packaging opening performance (Bell et al., 2016; Bell et al., 2017b; Bell et al., 2013: Canty et al., 2013; Świda et al., 2019; Yoxall et al., 2019; Wenk et al., 2016).

Our results are consistent with previous literature identifying interaction issues with bottles, cheese thermoformed trays, the use of foil seals, and sealed pouches (e.g., Bell et al., 2016; Bell et al. 2017b; Canty et al. 2012; Wenk et al., 2016). We also added new evidence by including packaging that has not been studied before in terms of usability to our knowledge, such as the chickpeas' rigid plastic container, the beverage carton packaging with different opening systems (milk and juice), and the cellophane roll-wrap with tear tape (crackers).

Regarding task efficiency, in this study we only found a significant difference between age groups in opening times for the thermoformed tray (laminated cheese). However, we identified a large opening time variability within the groups (Table 4), showing older adults' diversity in terms of packaging interaction, and the influence of more factors than just age.

The packaging that took the longest mean time to be opened in both groups was the chickpeas' rigid plastic container with peelable foil seal and cardboard cover (Group A, M=36.1, SD=19.78, Group B, M=59.86, SD=39.04), followed by the crackers' cellophane roll-wrap with tear tape for Group A (M=33.1, SD=19.31) and the thermoformed tray with easy open system (laminated cheese) for Group B (M=38.71, SD=21.47), which had already shown interaction issues in previous studies (Bell et al., 2017b; Wenk et al., 2016).

Packages that took the longest time to open also included the highest number of errors made by one participant during the opening process. For instance, although older adults showed they were willing to take their time to understand how the unfamiliar pre-cooked chickpeas' packaging worked, opening the packaging was challenging due to the various packaging components (cardboard cover, plastic lid, and foil seal), design issues such as the lid's confusing affordance inviting to "twist" instead of "pull," and issues with strength and dexterity to open the foil seal, which have also been found in previous studies (Bell et al., 2013; Bell et al., 2017b; Canty et al., 2012).

As for errors, we found that the most common error during opening was using utensils such as knives and scissors when there were seals or easy open systems they could not perceive or open. This finding was consistent with previous studies showing older adults' use of external elements and the risk involved (Ford et al. 2016; Sudbury-Riley, 2014; Wenk et al. 2016). Visibility was another issue previously identified in the literature (e.g., Wenk et al., 2016). Many participants did not notice easy open systems that were not highlighted, such as the easy-open golden ribbon in the cracker cellophane roll-wrap packaging. Another case was the mayonnaise jar. Although many studies focused on jar opening (e.g., Rowson & Yoxall, 2011; Yoxall & Janson, 2008; Yoxall et al., 2006; Yoxall et al., 2010), our participants only showed difficulties attempting to remove the transparent plastic seal with pre-cut marks placed on the lid, which was difficult to see.

On the other hand, the packaging that took the shortest amount of time to be opened was the PET water bottle with screw cap for Group A (M=7.8,

SD=4.29) and the aluminum can with a ring pull tab for Group B (M=6.43, SD=4.93). In both cases we did not identify errors, although some participants showed difficulties to exert the required force. Previous studies showed that there are older adults who cannot open a bottle (Bell et al., 2013).

As for pouring and spillage, although Świda et al. (2019) and Duizer et al. (2009) found that older adults expressed problems with these actions, we observed that participants in our study did not present difficulties.

For packaging closing times, we did not find significant differences between age groups. Since the process frequently consists of the opening with a reversed action sequence, users do not have to find a strategy, and thus times are shorter. We observed that participants had difficulties to seal the closing system at the first attempt. Participants also expressed the need for external elements to help closing the packaging, such as rubber bands or tape, responding to the use of smaller portions identified by Ford et al. (2016). Packaging producers should design effective closing solutions that are easy to use and do not require external elements to ensure food preservation.

To conclude, despite packaging industry efforts to provide easy-open systems, we observed that if they do not consider an ergonomic, intuitive, and inclusive design, with clear signs and affordances, they can lead older adults to find alternative strategies that may not be efficient, comfortable, and safe. We also identified that re-usable packaging needs to be improved in order to solve the closing system effectively, to protect the food content and avoid the need of external elements. Usability testing proved to be an effective methodology to identify packaging design interaction barriers for older adults. This approach can be applied with products already available on the market and with prototypes during the design process. We hope that our results can provide useful insights for packaging design and engineering, to create solutions that protect the product and are easily used by all.

4.1 Limitations and Projections

The sample size in this research responds to the requirement for usability studies; however, it is a very small sample for statistical analysis. The comparison analysis allowed us to only explore performance differences between samples, but it cannot be considered representative of the population. Further studies will support our results with larger sample sizes. Moreover, future studies could identify older adults' specific groups or "user personas" (Miaskiewicz & Kozar, 2011) that could be studied and compared.

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