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AN EYE-TRACKING STUDY TO ASSESS THE PERCEPTION OF USABILITY AFFORDANCES OF ASSISTIVE DEVICES
AN APPLICATION TO JAR OPENERS

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ABSTRACT

Some assistive devices (ADs) aim to ease elders performing daily activities by changing postural and strength requirements. Elders usually have cognitive lacks too, making AD usability perception an important issue. Usability perceptions arise from the affordances conveyed by the AD: design features should act as signifiers transmitting opportunities of how to use the AD. This study assesses the perception of jar openers usability. Eye-tracking (ET) data from 56 subjects were used. Rendered images of 6 ADs were shown, in 2 versions: with and without rubber on the grip area. Each slide showed the 6 ADs, each AD image being an area of interest (AoI) to be tracked. The participants ranked the ADs in the next usability affordances: comfort, effort level, easiness to grip, easiness to use, lid slippery and robustness. For each affordance, they were eye-tracked while deciding the best AD, and afterwards they ranked the other ADs. The ranks were transformed into scores, and their correlation with ET parameters (decision time and number of fixations on each AoI) were studied, along with the effect of the rubber on the scores. Heat maps were also analyzed to identify the signifiers of the ADs that attract attention on usability. The results showed the potentiality of ET to study the perception of ADs usability affordances, and that the addition of rubber on the grip area of the jar openers or the material and shape of the lid area have an effect on their understanding and use.

Keywords: *assistive devices, eye-tracking, usability affordances, signifiers, product design*

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1 INTRODUCTION

The grasping and manipulation capacity of the human hand is key for the development of activities of daily living (ADL), both in personal and work contexts (Bullock et al., 2013). This ability is diminished in old people, and is aggravated by pathologies with high prevalence, such as hand osteoarthritis (HOA). Household management tasks, especially those requiring high grip force combined with twisting movements, have been identified as the ones generating more functional problems in HOA patients (Kjeken et al., 2005). In particular, the jar opening task is one of the most limiting activities for old people (Weeks-Levy et al., 2020).

In this home context, assistive devices (ADs) may improve the quality of life of the elderly by increasing their autonomy. ADs facilitate the execution of certain tasks, protecting the structures of the hand against deterioration (Duruöz, 2014). ADs are designed to compensate the loss of strength and/or dexterity (Shipman & Pitout, 2003), improving the functional capacities of people with hand pathologies, such as range of motion, muscle strength, resistance and manual dexterity (Kjeken et al., 2011; Rogers & Holm, 1992).

However, ADs are often rejected because of several reasons, most times due to problems that can be solved with an appropriate design. E.g., many ADs require too high physical demands of strength and/or dexterity (de Boer et al., 2009) or even cognitive ones, since at certain ages it gets harder to understand the operation of new devices (Yusif, Soar, & Hafeez-Baig, 2016). In order to achieve its objective, among other requirements, an AD must be effective and safe, easy to use and accepted by the user. In addition, in the emotional field, it is essential that the AD transmits positive emotions in order to guarantee its use. Positive emotions are associated with greater security and independence, while negative emotions can lead to frustration, stigma, and disinterest in the use of ADs (Chen, 2020). Both the meaning of the product and the transmitted emotions must be taken into account when the product preferences are established, considering the user's criteria from the beginning of the development process (Agost & Vergara, 2014). In conclusion, it is essential that the person accepts to use the product and feels natural and comfortable using it, and this is something that is not fulfilled by most ADs for manipulation.

Furthermore, the user should be able to understand correctly how a product works, for which the information transmitted by the AD must be clear. Usability perceptions arise from affordances, which can be anything that it is possible to do with a product, making the desired action possible. Moreover, if the affordances are not intuitive, signifiers (design elements capable of transmitting opportunities of how to use the product) should be used to indicate them. Adding signifiers is the best way to discover the affordances and make sure that the feedback is clearly understood by the user (Norman, 2013).

Affordances of some ADs have been assessed in recent studies. A study (Lucaites & Pagano, 2018) evaluated walking ADs used by old people, and showed that the user experience is a fundamental factor to ensure that users better understand the functioning of the AD and use it appropriately. Several studies have used Eye-Tracker (ET) technology for the assessment of affordances. In Burlamaqui and Dong's study (2017), a series of subjects observed a product for a certain time and then tried to explain, through a questionnaire, its functioning. They found a

strong correlation between the perception of affordances and the explanation of the product's function from the questionnaire results. Number of fixations, time to first fixation in AoI, and first fixations in AoI ET metrics were analyzed, but none of them seemed to successfully identify the intended affordance. Regarding the most representative design aspects, Berni et al. (2020) found, through the use of ET, that the most creative characteristics and most original elements of the products are essential to capture the design intentions by the users. Although the jar opening task is recognized as a very limiting activity for old people, jar openers usability affordances have not been investigated yet, which might be key to improve their design and promote their use.

This study aims to analyze the usability perceptions of the affordances conveyed by jar openers: comfort, effort level, easiness to grip, easiness to use, lid slippery and robustness. ET technology is tested to assess the jar opener signifiers, with the final goal of developing general tools to improve the quality of life of the elderly and facilitate performing ADL.

2 METHODOLOGY

The study analyzes the perception of usability affordances of 6 different models of jar openers and suggest the design features that can act as signifiers, transmitting information about how to use the AD, with special emphasis on the use of rubber in the gripping area.

2.1 Participants

Sixty-three candidates were recruited for an ET experiment, most of them (about 80 %) students and staff of the Universitat Jaume I, Castelló, Spain. Candidates with an ET registration data percentage below 75 % (3) or with inconsistent answers (4) were discarded. Finally, data from 56 participants (26 women and 30 men) were used for the analysis. The participants had a representative coverage in age: 16 subjects under 35 years, 21 over 45.

The participants were not allowed to manipulate the ADs. At the end of the experiment, they were asked whether they were familiar with the jar opener models: 33.9 % claimed not to know any of the models assessed, 37.5 % knew one of the models, and the rest knew two or more.

All of them had normal or correct-to-normal vision. The ET device (Tobii Pro X2-60) was placed below a 24-inch computer monitor. The participants sat in front of the screen, at an approximate distance of 60 cm. All participants were calibrated at the beginning of the test.

2.2 Stimuli and procedure

Six models of jar openers in two different versions, without and with rubber on the grip area (Figure 1), were chosen for the study. The jar opener models were selected so as to be varied in grip and type of effort used in the opening action.

Two ET projects (A and B) were designed, so that each subject assessed the 6 models but in only one of the versions: Project A had models 2, 4 and 6 with rubber, and models 1, 3 and 5 without rubber, and Project B with the opposite version of the 6 models. The participants were randomly allocated to the projects. Due to the exclusion criteria, subjects per project were slightly different: project A with 27 subjects, and project B with 29.

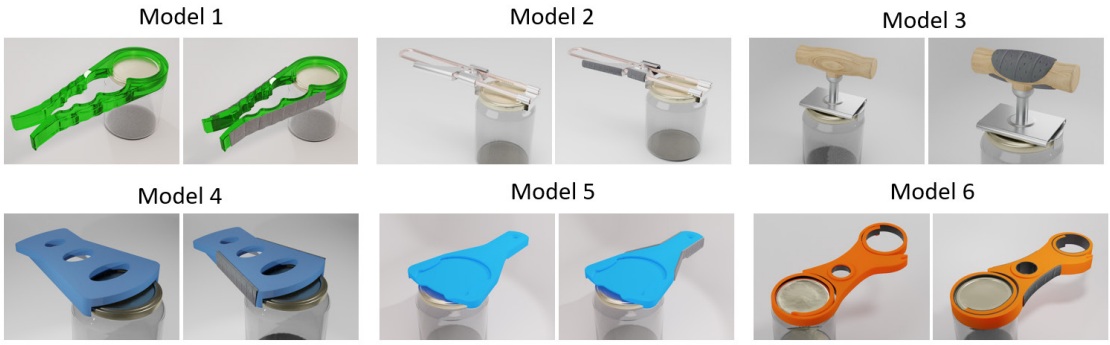

Figure 1. The 6 jar openers models with their two versions: without rubber (left) and with rubber (right)

To assess the functionality, each subject ranked the jar openers in 6 different usability affordances: comfort, effort level to use it, easiness to grip, easiness to use, lid slippery and robustness. The 6 models were shown simultaneously in a stimulus as in Figure 2, for each affordance. The jar openers were shown in their working position (placed over the lid jar), except for 'lid slippery' affordance, to show properly the AD area that contacts the lid. The models were located in a different position in the screen for each question, to avoid its effect on the results.

Figure 2. Examples of the stimulus used (Spanish version) for the affordances 'easiness to use' (left) and 'lid slippery' (right) in Project A

In order to rank the jar openers for each affordance, the same stimulus was shown 4 times, so that each time the subject was asked to select (in this order): the best jar opener model, the second best, the worst and the second worst. Each affordance appeared randomly for each subject. As a result, a total of 24 images (6 affordances x 4 questions per affordance) for each project were generated, which represented the stimulus set. The subjects could read the question at the bottom of the screen (Figure 2), and answered by clicking on the selected model.

2.3 Data analysis

The image of each of the 6 jar openers in each stimulus was defined as an Area of Interest (AoI), i.e., participants' attention was tracked in each of the 6 rectangles containing each model. Several metrics from these AoIs were obtained from the subjects' eye movement only during the first question posed for each affordance: TFD (Total Fixation Duration in seconds in each AoI); FC (Fixation Count, number of fixations in each AoI); and Click Count, to identify the AoI selected.

For each affordance, a score was assigned to each jar opener from the Click Count metric of the 4 ranking questions posed to the participants: +2 for the best, +1 for the second best, –2 for the worst, –1 for the second worst, and 0 for the non-selected models.

The results were analyzed with SPSS statistical software (IBM SPSS Statistics 27). Descriptive statistics of TFD and FC metrics per affordance and scores are shown. First, with the scores, error bars graphs were obtained for 95% confident intervals for means. T-student tests were performed, one per each affordance and model, to investigate whether the rubber (independent variable) has a significant effect on the scores (dependent variable). ANOVAs were performed, one per affordance, also with the scores as dependent variable, and the model as the independent one, to check whether the scores are significantly different between models in each affordance. Thirdly, Spearman's correlations were computed, in order to measure the association between the scores and ET parameters (TFD and FC metrics) for all the affordances altogether.

Finally, heat maps for the stimulus shown when selecting the best model for each affordance were analyzed to understand which parts of the jar opener attract the participants' attention on usability. Heat maps illustrated the mean number of fixations for all subjects with a color scale. The effect of the rubber was assessed from a qualitative analysis of the heat maps.

3 RESULTS

Table 1 shows the descriptive statistics of TFD and FC per each affordance and score. Last row shows the statistics of all the data.

Table 1. Statistics of TFD (seconds) and FC (number of fixations) per affordance (comfort, CM; effort level, EL; easiness to grip, EG; easiness to use, EU; lid slippery, LS; robustness, RO), score and globally

		TFD (s)			FC		
		Median	P5	P95	Median	P5	P95
Affordances	CM	0.65	0	3.17	4	0	14
	EL	0.85	0.12	3.80	4	1	19
	EG	0.58	0	2.75	3	0	12
	EU	0.64	0.06	3.17	3	1	15
	LS	0.78	0.12	3.77	4	1	16
	RO	0.57	0	3.41	3	0	13
Scores	-2	0.46	0	1.77	3	0	10
	-1	0.48	0	1.68	3	0	9
	0	0.55	0	2.32	3	0	11
	+1	0.80	0.10	3.80	4	1	16
	+2	1.79	0.57	5.52	8	3	26
Global data		0.67	0	3.41	4	0	15

Figure 3 shows the error graphs of the scores of each affordance for each jar opener. Models with significant differences in the scores (ANOVAs) depending on the presence of rubber are marked with an asterisk. In general terms, the assessment depends on the affordance, and the rubber added on the grip area was positively assessed in most models and in all of the

affordances. Model 1 seems to be the most affected by the rubber. In addition, significant differences ($p<0.001$) in the scores were found between models in all the affordances.

The Spearman's correlations were significant (at 0.01 level) between scores and the ET metrics (correlation coefficient with TFD was 0.423, and with FC was 0.394).

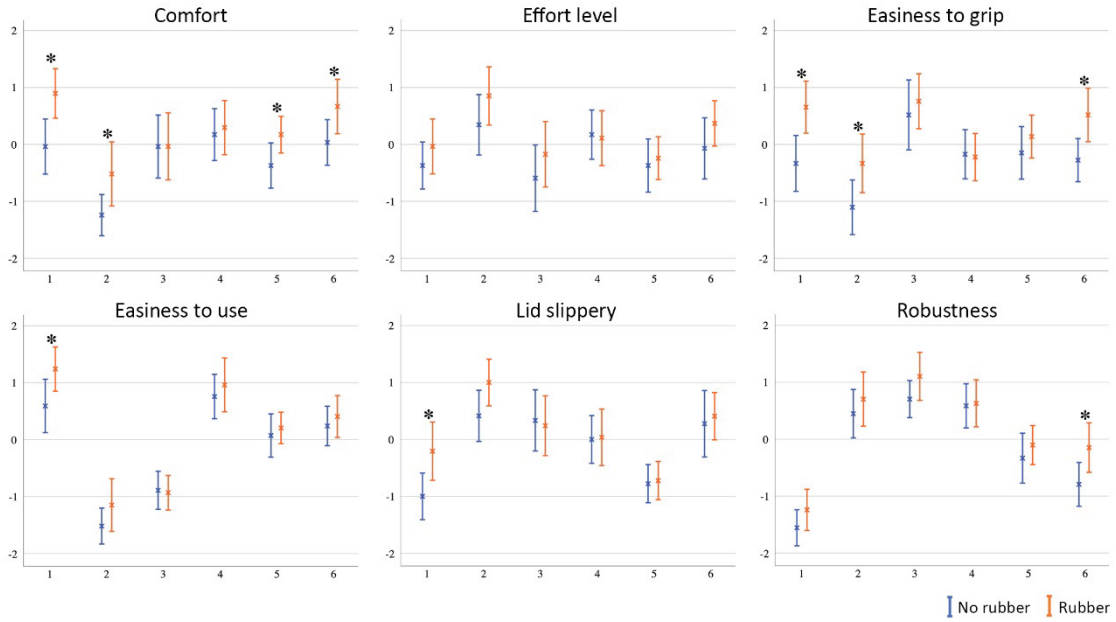

Figure 3. Confidence intervals (95 %) for mean of the scores. Models with significant differences ($p<0.05$) in the scores depending on the presence of rubber are marked with an asterisk.

Finally, figure 4 shows heat maps for each affordance, in Project A and B. Figure 5 summarizes the results of the heat maps for the 6 models, per affordance, distinguishing per AD zones: grip area, the jar area that is in contact with the lid, and rubber (for rubber model version).

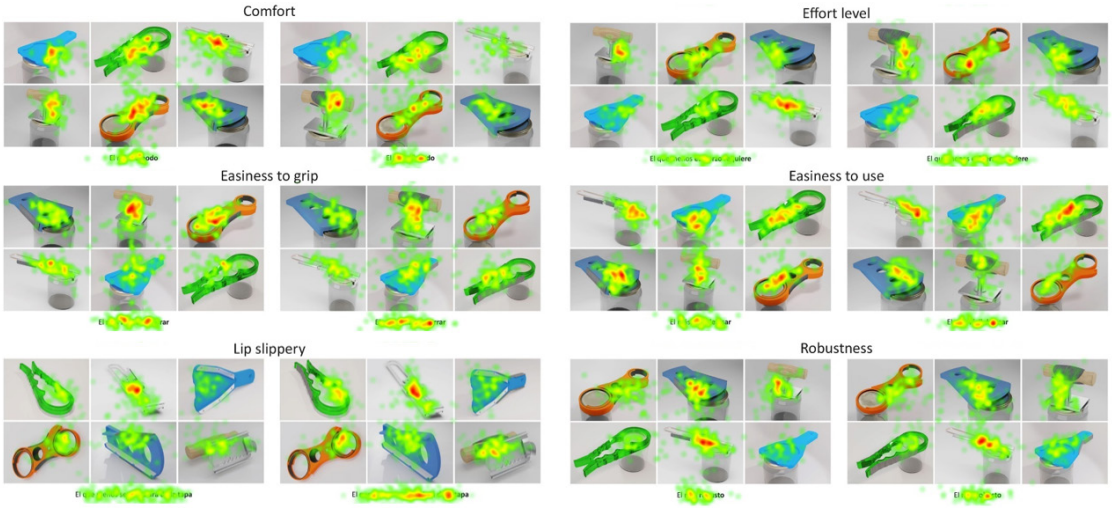

Figure 4. Heat maps of Project A (on the left of each affordance) and Project B (on the right). Red color means higher attention.

In general terms, the attention in the established areas depends on the affordance assessed. The lid area was paid high attention in both versions. On the other hand, the intensity on the grip

area depends on the model version, being higher in the rubber version. The rubber was more observed in 'comfort' and 'effort level' affordances.

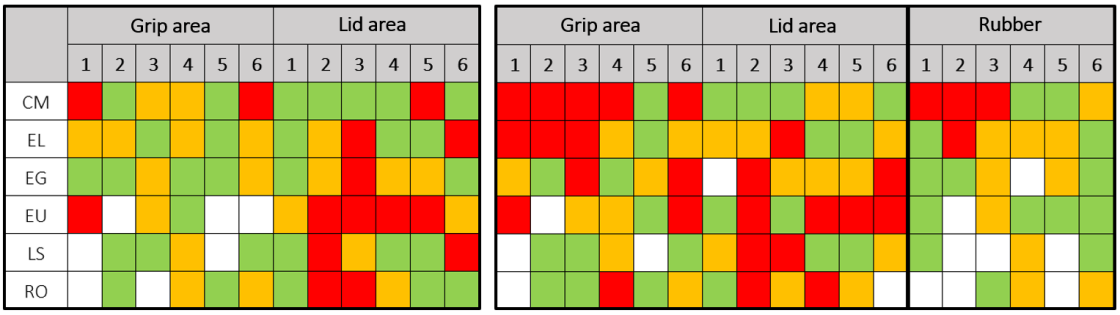

Figure 5. Summary of heat maps for the 6 models without rubber (left), and with rubber (right), per affordance (comfort, CM; effort level, EL; easiness to grip, EG; easiness to use, EU; lid slippery, LS; robustness, RO). Red-yellow-green color for higher to lower attention, white color for no attention

4 DISCUSSION

This study aims to analyze the ADs usability affordances of 6 models of jar openers and their 6 modified versions (adding rubber on the gripping area) through ET technology. Although getting familiar with the product favors to understand its functioning and proper use (Lucaites & Pagano, 2018), in no case the participants manipulated the ADs, so that all the information came through visual stimuli, because the goal was to assess how the design features of the ADs affected the perception of the affordances at first glance.

The usability affordances of the different models were assessed based on the scores assigned from the Click count metric from the ET, highest scores meaning greater perceived affordances. These results can help in the design of ADs with a high affordance transmission, in order to promote their acquisition and use. In addition, heat maps can help to identify the ADs signifiers that attract the subjects' attention for each usability affordance. Here are the features that seem to favor higher affordance transmission for the different affordances:

- Comfort: Shape, rubber and material seem to have an important role. Models 1 and 6 with rubber obtained the best scores. Both models are long, with a large gripping area, and made of plastic. In contrast, model 2, made of steel, was considered the worst. The grip area received high visual attention, especially in model 2, which could be attributable to its complex design, which become into a signifier difficult to be understood. The rubber acted as an important signifier in models 1, 2 and 3, with higher attention on the grip area for the rubber versions.
- Effort level: Shape and material seem again to be key. Model 2 is the best scored, especially the rubber version. This model is metallic and has a lever shape, which can be clearly seen as a signifier of reduction of the effort required. However, models 1 and 6, with a similar lever shape, had lower scores, maybe because their material (plastic) acted as a negative signifier. Highest attention was paid to model 2, that had the best scores, especially to the grip area and the rubber. However, model 4, also with high scores, had less attention,

probably attributable to the simplicity of model 4 against model 2, so that it helped to understand its affordances, and subjects needed less attention time to assess it.

- Easiness to grip: Models 1 and 6 in their rubber versions are high scored, together with model 3, in its two versions. The grip area of these models has attracted high attention. The design of the handle in model 3 might have acted as a familiar signifier to grip. In the rubber versions, the rubber was observed with more attention, thus the rubber helped to understand the affordance. In contrast, model 1 and 6 without rubber have received low attention: their grip shape acted as a better signifier to understand the easiness to grip. I.e. rubber and shape seem to act as signifiers in this affordance.
- Easiness to use: Simplicity of the mechanisms seems to make the difference. Models 1 and 4 in both versions had the best scores, in contrast to models 2 and 3, whose mechanisms become into complex signifiers to be understood. Besides, all the scores are similar for both versions and all the models present similar attention paid, being the lid area the most observed. This may point that to evaluate the easiness to use, it is more important to know how the jar opener works (how it grabs the lid to turn it) than how has to be grasped. Therefore, in this affordance, the rubber is not a signifier.
- Lid slippery: Material and shape of the region that has to be in contact with the lid might have been key. Models 1 and 5 were assessed as the most slippery because they are made of non-texturized hard plastic (model 1) or metal thin edge (model 5) signifiers in the area to grip the lid (Figure 6). These two models attracted low attention, probably because these signifiers were strongly related to slippery. Models 2 and 3, assessed as the least slippery, were also metallic in the lid area, but in this case with a protruding flange that has probably acted as a positive signifier against slippery (Figure 6). Again, these models were the most observed, probably because the complexity of the mechanism made the participants to doubt. Models 4 and 6 are also high scored, although with medium attention, and they have a soft material (rubber appearance) in the region to be in contact with the lid.

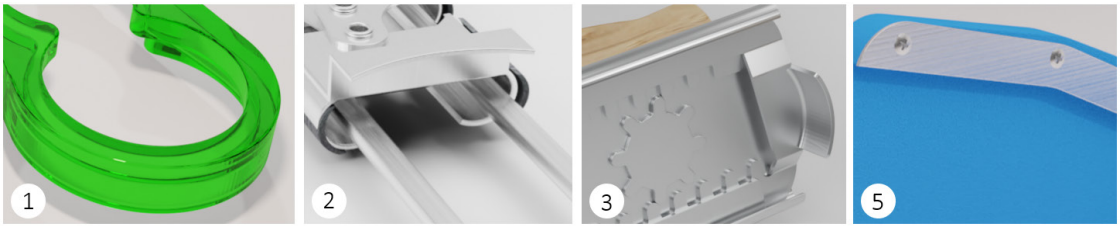

Figure 6. Material and shape details of models 1, 2, 3 and 5

- Robustness: The material might have been the reason to assess models 2 and 3 (made of steel) with high scores. The most observed models in this affordance were the best scored, especially the lid area, steel probably acting as a positive signifier of robustness. Model 4 was also assessed as robust, maybe because it is made out of just one piece, without moving elements, and with a higher thickness of the material, although being plastic. In contrast, model 1 was assessed as the worst, probably because the product seems to be made of fragile plastic. It was also the least observed.

In general terms, regarding the scores obtained, the rubber improved the assessment of the affordances in most of models. In particular, model 1 was the most affected by the rubber, increasing significantly its scores in comfort, easiness to grip, easiness to use and lid slippery, so that we can conclude that rubber acts as a signifier that improves its perceived usability affordance. Shape and material, in special material of the region of the openers in contact with the lid, can be acting also as signifiers for the perception of several usability affordances.

AoIs have been used to obtain quantitative data through ET metrics. Contrarily to Burlamaqui & Dong (2017), we have been able to find metrics that help to assess the affordances. A significant correlation has been found between the TFD and FC metrics with the scores, showing that the total time spent observing the product and the number of fixations in each AoI is related to the usability perceptions, i.e. the models that best show the affordances are given more attention. However, this can be affected by the way in which we have performed the study, as we have used the ET metrics when the participants were looking at the best model for each affordance. Effort level, easiness to use and lid slippery affordances seem to be more complex to assess according to the higher values of TFD and FC metrics, and they might need clearer signifiers.

Future work could look for additional ET metrics to address the study of ADs affordances, and could consider more specific AoIs to obtain a more detailed effect of different signifiers. Old people, or even people with pathologies that affect hand function, could be considered to participate in a future ET study in order to obtain results that could have a real impact on the quality of life of the elderly.

5 CONCLUSION

This work has analyzed the usability affordances of jar openers to identify the relevant signifiers affecting the perception of the affordances. ET technology has been checked to be a potential useful tool for the study of ADs signifiers. Jar opener models can be improved by adding the identified features that make easier their understanding and use, such as the addition of rubber on the grip area of the jar openers or the material and shape of part in contact with the lid.

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