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The influence of product digital visual presentation on purchase willingness: effects of roundedness axes and degree

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Abstract
The research examines the influence of digital visual product package presentations on perceived purchase willingness. Subjects pairwise compared the graphical stimuli displayed on a computer monitor. Gathered purchase willingness preference weights were calculated by means of the Analytic Hierarchy Process technique. Two studies focused on the package edge roundedness effect applied along different axes are reported. The first one included the following factors: *Roundedness axis* defined on three levels (*X*, *Y*, *Z*) and *Roundedness degree* also specified on three levels (*Small*, *Medium*, *Large*). The second involved *Roundedness type* (two levels: *All edges rounded*, *Only sides rounded* – along one axis) and *Roundedness degree* (*Tiny*, *Small*, *Medium*, *Large*). Both package *Roundedness axis* and *Roundedness degree* influenced perception and purchase willingness. This research extends existing knowledge by presenting empirical evidence on how a variety of product digital forms influences visual perception and purchase willingness. The results deliver useful and detailed information for practitioners and the outcomes may be applied as guidelines for computer graphics designers preparing visual appearance for articles in electronic shops, websites, banners, or advertisements displayed in networked screens.

Keywords Digital package perception · Visual processing · Roundedness axis · Electronic commerce · Marketing

1 Introduction

In today's highly digitized world, the importance of illustrating products in a way that supports the customer's willingness to buy is ever more critical. Aesthetically pleasing products, their packaging design along with graphical presentation in either electronic shops or online advertisements may positively influence potential buyers' perception and, therefore, have an impact on purchase decisions.

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Product visualization is the process of creating visual representations of various goods and services. This can be done by designing, demonstrating, or advertising through physical means such as building real-size or scaled mockups and models. Nowadays, visual representations of products are often constructed using information technology methods and tools. To facilitate communication of product design and its features to stakeholders, various systems, or computer software can be utilized. These multimedia tools enable the creation, editing, and sharing of content, such as images, videos or animations. They play a crucial role in digital product presentations, which are designed to showcase product's features, benefits, usage, and provide additional information about them.

Generally, the interest in an effective product presentation is not new and has been subject to investigation for a long time. Usually, a given article is presented in packaging which typically serves the following functions [63]: containment, protection, convenience, and communication. Currently, situations when a product is physically not available, for instance, software, music, or various kinds of services, are not rare. It sometimes occurs that not only products, but also their packaging exists only in a digital form. In such cases, the role of a package is actually limited to providing information to customers. Because of this, static visual message conveyance is gaining in importance for both scientists and practitioners. On the one hand side, psychologists or neurophysiologists try to discover how people respond to specific factors related to graphical stimuli and explain it by proposing formal theories. On the other hand, marketing research is more focused on how these general rules influence human behavior in a real environment or in a specific context. The present paper is a continuation of the latter trend and systematically examines, in two studies, inspired by results from more general fields of science, the impact of the packaging presentation form on the potential buyers' subjective purchase willingness. The general importance of research on packaging and a detailed discussion of the relevance of its various aspects was presented, e.g., by Sample and colleagues [67].

Although there was research dealing with how various packaging features, such as rounded vs. angular shapes, can influence consumers' perceptions, this study provides a more specific and detailed approach. The roundedness factor is investigated along different axes of the package and involves a number of degrees. Moreover, current studies, unlike almost all prior studies, involve a product that, according to Vaughn [77, 78], belongs to the high involvement class of goods.

One should also notice that the online product presentation context examined in the present study is associated with some unique features that are qualitatively different from in-store displays and real packaging. Packages presented online may not exist in reality or it may even be impossible or too expensive to produce them. Some of the digital package designs could cause practical problems if they were physically manufactured, e.g., the package largely rounded along the Z axis examined in the current study would probably not stand firmly on the shelf. Other package shapes might be troublesome while storing or transporting.

Another difference is concerned with the lack of haptic interaction in online purchases, which was identified as an important factor influencing purchase decisions [16]. The absence of tactile experience can influence the perception of visual components. Various aspects of packaging are becoming important for practitioners and researchers who are looking increasingly closely at the details of the product presentation. For example, Togawa et al. [74] focused on the influence of visual packaging design on flavor perception and healthy eating decisions, whereas Simmonds and Spence [69] examined how presenting products on, or through packaging impacts consumer perceptions and purchase behavior. Other sensory aspects of package design are thoroughly discussed in the work of Krishna and colleagues [41].

In the following sections, a brief literature review regarding visual aspects of human processing together with research on digital and real package demonstrations is provided. To provide an appropriate context and reinforce the importance of product packaging digital presentation, the paper outlines the strong relationships between this concept and various multimedia tools and systems. It is supported by relevant references. Based on this, specific hypotheses are formulated. Next, there are detailed reports from the two studies including results, statistical analyses, and discussion of findings. General discussion along with limitations and future research end up the paper.

2 Related work

2.1 Multimedia systems and tools regarding product visualization

There is a close relationship between multimedia tools and digital product presentations. Various tools enable the creation of high-quality product and its packaging images and videos that can be used to showcase different aspects of a product and provide a better understanding of it. Computer-aided design (CAD) software is one of the key systems involved in detailed product visualization [11, 26, 39]. This software allows designers and advertisement specialists to create two and three-dimensional models of products, including their geometry, materials, and textures [70, 79]. CAD software typically includes a range of tools for modeling, rendering, and animation. Some studies have used CAD software to generate product visualizations and employ them in marketing research [29, 49, 50, 59]. The latest technological developments can significantly facilitate content creation by transforming free-hand paper sketches into realistic three-dimensional digital objects [47]. Interestingly, even sketches hand-drawn in the air can be used for generating digital object representations or searching purposes [44].

In addition to displaying static rendered images, it is also possible to create animations for product digital presentation. In this way, not only the basic geometry of a product, including its shape and size, is presented, but also motion and movement can be incorporated [27]. Animations can show product features from all angles (see, e.g., [53]) and demonstrate the kinematics of movable components [33]. Moreover, they allow for simulations presenting how a product might behave in different conditions and environments, or show how it can be assembled or disassembled [38]. Although creating animations is usually more demanding than elaborating still images, recent advancement can make it simpler by providing appropriate methods and tools, such as automated video creation (see, e.g., [32, 43]).

Other systems involved in product visualization can include virtual and augmented reality platforms, which allow users to experience and interact with products in a simulated three-dimensional environment [76]. These systems can be particularly useful for product demonstrations [27] and user testing, as they allow customers to experience a product in a more immersive way. An example is the application of so-called situated visualization. A brief description of how this type of information support may be incorporated and facilitate decision-making in everyday real-life shopping is provided, e.g., in [48]. Taking advantage of mixed reality, product visualization can play an important role during design and production. It can reduce costs of developing new or changing existing products as well as speed up the assembly process or training inexperienced workers (see, e.g., [14, 30, 75]; for a comprehensive review, refer to [25]). This area of research and applications is becoming more popular as augmented reality is increasingly common and appropriate software for visualization is not necessarily expensive [52, 73].

Finally, multimedia tools related to the Internet facilitate the sharing of digital product presentations. They can be easily distributed on websites, social media platforms, and other digital channels, allowing potential customers to access the information they need at any time and from practically any place in the world.

2.2 Objects' shapes and their human visual perception

Object shape perception has been subject to investigation by many researchers from various fields of science. One of the interesting directions is the subjects' response to curved versus angular objects. More than 55 years ago, Berlyne [8, 9] suggested that people may link angular figures with energy, toughness, and strength, while rounded contours with approachableness, friendliness, and harmony. The latter set of traits commonly seems to be more attractive, thus, curved shapes should possibly be better liked than the edgy ones.

Particularly extensive investigations in this regard were reported by Bar and Neta in their three papers [4–6]. In the first study, they examined 117 pairs of real, every day three-dimensionally looking items plus 23 English characters and 140 pairs of two-dimensional meaningless patterns. All graphical objects' pairs had the same meaning and were differentiated only by the curvature of their contours. The study clearly showed that people preferred more curved than edgy shapes. They argued that sharp transitions in contours might be associated with a sense of threat and therefore evoke negative attitudes. This hypothesis was further pursued in the next work of Bar and Neta [5]. In this study, they took advantage of functional magnetic resonance imaging (fMRI) of the human brain to investigate this phenomenon in a series of three experiments. The obtained data confirmed their previous results showing reduced likings for sharp-angled objects, which was accompanied by an increased amygdala activation for this condition versus curved objects. Since such brain activation is typical for an increased sense of threat and danger [1, 81], they confirmed their conjecture that objects may be subconsciously perceived in this way based solely on their contours' features. In the last study, Bar and Neta [6] discuss their previous results and embed them in a more general theory describing how people make fast predictive judgments based on characteristic objects' features.

Stimuli examined in the papers described above either presented two-dimensional shapes or included three-dimensional looking objects that were not manipulated in the experimental design. Some of the other investigations focused on persons' attitudes towards two- or three-dimensional objects being either displayed in various ways or deformed according to specific rules. Silvia and Barona [68], for instance, in their two experiments, examined people's preferences towards the angularity degree. They reported a strong influence of this effect both for arrays of circles and hexagons as well as for random polygons and their rounded versions. They controlled for symmetry, prototypicality, and balance. One of the especially interesting works in the neuroscience field was conducted on macaque monkeys by Kayaert et al. [36]. They examined the responses of neurons located in the inferior temporal cortex to various three-dimensionally looking shapes. Unlike in some previous studies, they manipulated the objects' shapes systematically in a fully controlled experiment. Later, Kim and Biederman [37] examined similar differences in objects' relations in humans.

2.3 Package designs and consumers' behavior

The importance of a package function concerned with communication with a customer has been acknowledged many years ago see, e.g., Dichter [21], Cowley [19]. Thus, it is not surprising that there exists a significant amount of research dealing both with classical packages and with their digital versions. Azzi et al. [2] reviewed and classified scientific papers in this area published between 1990 and 2011. Among the most important fields of research regarding package design, they include marketing and communication.

Studies confirmed that various types of package designs have a significant effect on peoples' brand impressions [56] and evaluation [46]. Packaging has also an impact on consumer price expectations [55] and this, in turn, influences final purchase decisions [10]. Reimann et al. [62] have shown that people prefer aesthetically pleasing packages – even if their prices were higher – over products of well-known brands in standardized packages. Based on fMRI data, they also noticed that people's affective product involvement was connected with aesthetic product perception.

In recent years, some studies focused specifically on consumers' responses towards packaging or its components. The package graphics design has been subject to investigation, e.g., by Westerman et al. [80]. They showed the importance of the shape, angularity, alignment, and orientation effects in a more specific context of design labels of water and vodka. An interesting investigation of Clement et al. [17] based on two eye-tracking experiments showed a statistically meaningful effect of packaging on human visual attention. The authors determined that the contour and contrast dominate the early stage of the product search. In a recent study, involving the analysis of yoghurt packages, Suzianti et al. [72] confirmed some previous results showing that rounded packages were better rated than the angular ones. By using conjoint analysis, they demonstrated that the shape factor was the most important in comparison with a font type and a color scheme. In light of these outcomes, the packaging shape effect on human behavior seems to be especially worth paying attention to. As far as the angular and curved shapes are concerned, Zhang et al. [83] provided some evidence that the liking of more angular or rounded shapes may be related to the interdependent self-construal. Their claim was confirmed in a field experiment where subjects' subjective attitudes towards shapes in actual corporate logos from culturally different countries were investigated.

3 Research hypotheses

A great body of literature concerned with the visual aspects of packaging has been focused on low involvement products classified by Vaughn [77, 78]. Among them, there were works examining packages containing chocolate and salt [45], orange juice, chocolate bars, pasta and biscuits [42], snacks [13], yoghurt [7, 72], jam [17], wine [57, 71], Champagne [22], vodka [80], shampoo [28], non-prescription drugs [34, 35]. Among a few papers that investigate other types of products, there is the work of Grobelny and Michalski [29]. They examined smartphone package designs differentiated by background colors, brand's name position in relation to the product's picture, and the typography of the brand name. In the current study, the trend is continued by analyzing smartwatch packages that draw noticeably more consideration than low-involvement items.

As it was presented in the literature review, there are studies concerning the perception of digitally presented three-dimensional looking objects, however similar investigations concerning virtual high-involvement product presentations are rare. Taking this into account and in light of the studies regarding curved and edgy shapes, the following hypothesis may be generated:

H1: Rounded packages have a more positive impact on customers' purchase willingness than classical cuboid shaped ones.

Although some studies dealt with package shape perception and its importance in human's purchase behavior, there is a significant shortage of research that investigates this factor in a more systematic way in diverse contexts. There is still a number of questions that need to be addressed and clarified. For example, it is not known whether rounding box package edges along a specific symmetry axis has an impact on human perception or, to what extent the various degrees of objects' curvature may influence subjects' purchase willingness. Thus, the following hypotheses were formulated:

H2: Applying curvature to package edges along X, Y, and Z axes does not influence customers' purchase willingness.
H3: Bigger degree of roundedness applied to packages increase purchase willingness.

These hypotheses are examined in Studies 1 and 2 presented in next sections.

4 Study 1: Effects of package roundedness axis and degree

4.1 Stimuli

Subjects were asked to assess their purchase willingness of a fabricated device which was displayed on the virtual package together with a fictious brand name. The product image used in this study was created by deleting any identification elements from the picture of a real device. Images of digital packaging were designed in 3D Studio Max environment version 6.0. All prepared 3D grey objects were based of cuboids having the depth (equivalent to the X axis from Fig. 1) of one unit, the height (corresponding to the Y axis) of three units, and the width (referring to the Z axis) of two units. These dimensions obey the so-called golden proportion, which according to many studies [20, 54, 60] is the most preferred one. The following two independent variables differentiated the digital product presentation: (1) Roundedness axis of which specified rounded edges and (2) Roundedness degree. The former effect was examined on three levels including X, Y, and Z axes of symmetry. The latter one involved three levels of roundedness extent. They were set at radii 0.1, 0.3, and 0.5 of a unit and named Small, Medium, and Large. As one of the box dimensions measured one unit, the roundedness degree could not be bigger than 0.5. The next levels were determined by decreasing linearly the biggest radius value using the 0.2 step. Based on these two factors, nine different electronic versions of the mockup packages were prepared. As a point of reference, a typical box with all sharp edges was also included in this study. A front view, grey scale picture of a smart watch without 3D perspective, was picked to minimize the influence of other factors on the results. All ten experimental conditions regarding package shapes together with axes' denotations are illustrated in Fig. 1.

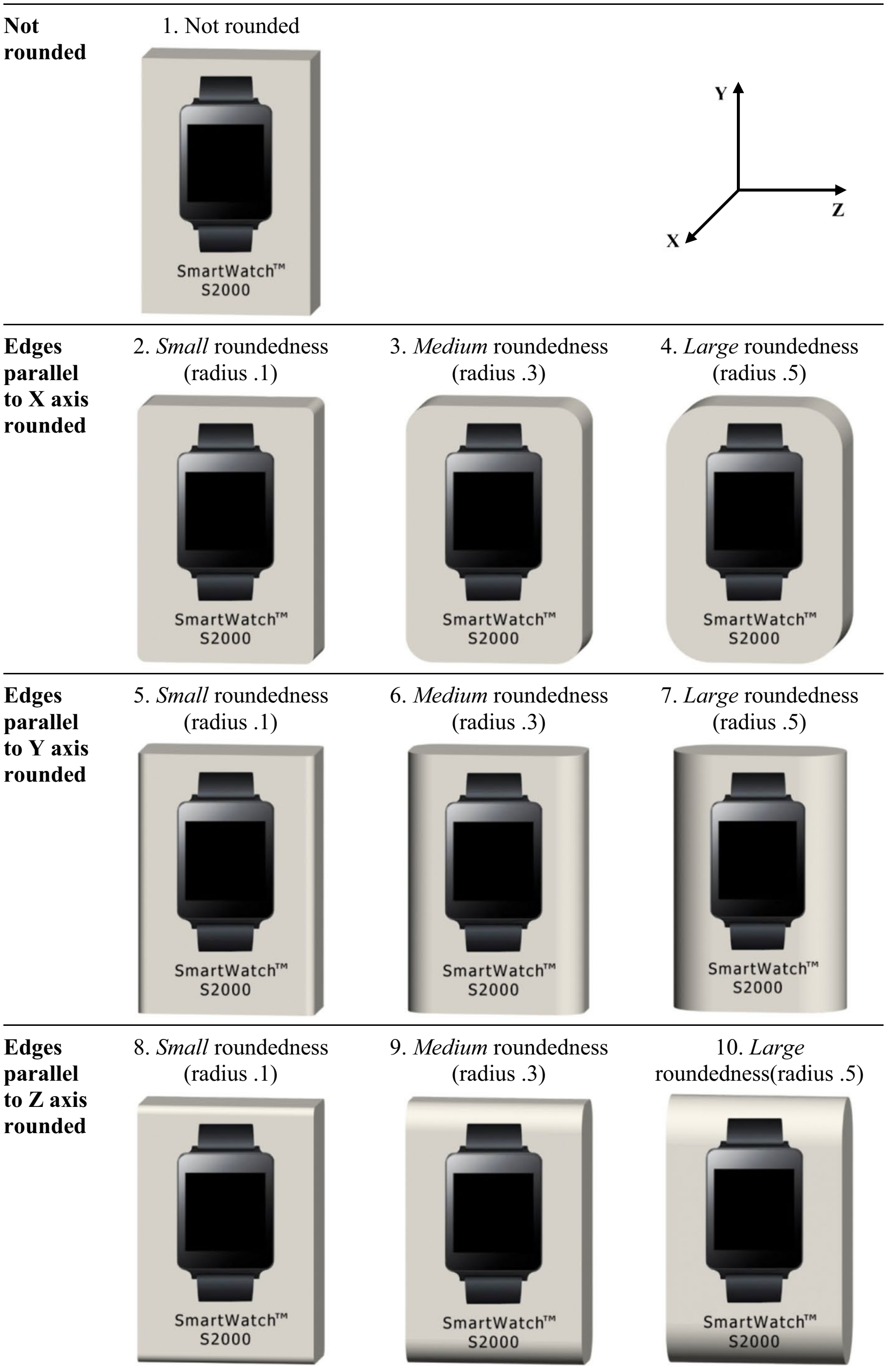


Fig. 1 Product presentation variants investigated in Study 1

4.2 Design and procedure

A full factorial design was used for package shapes, so each participant evaluated all ten experimental conditions, namely, three Roundedness axes of symmetry {X, Y, Z} × three roundedness degrees {*Small*, *Medium*, *Large*} plus one classic box without any edges rounded. These conditions were examined within subjects. Information about the goal and the general procedure of the experiment was presented to all participants before they gave informed consent to take part in the study. At the beginning, they answered some typical questions about themselves such as gender and age. Then, the proper part of the examination took place. The subjects pairwise compared the product package pictures appearing on a computer monitor.

They were told to choose this version of the digital presentation, which would better persuade them to buy the displayed product. The degree of their preference was to be specified on the following scale: *No preference*, *Somewhat more*, *More*, *Much more*, and *Decidedly more*. Pairwise comparisons are considered to provide more precise results than a direct ranking of assessed variants [40]. However, this method requires significantly more effort from subjects because the number of comparisons (c) increases quickly with the number of objects being evaluated (n), and follows this formula $c = (n^2 — n) / 2$. Because this study involved ten package variants, the number of necessary comparisons amounted to (100—10) / 2 = 45.

The digital product packages were displayed by an application written in a *Microsoft Visual Basic*, (version 6.0, service pack 6.0) environment. The software controlled the random presentation of appropriate pairs of pictures. The left–right location of variants within a single comparison was also set at random. The illustration of the software with an exemplary comparison is demonstrated in Fig. 2.

Fig. 2 An exemplary single comparison displayed by experimental software

The same application collected and processed participants' responses, saved them in a relational *Microsoft Office Access* (version 2003) database, and later exported the data to a statistical package (*TIBCO Statistica*, version 13.3).

The pairwise comparison results for a particular participant were mathematically processed further by constructing a square symmetric matrix, denoted as $\mathbf{PR}_i$, where i represents the participant number. The matrix contained dominance values of each assessed variant over every other variant. To make the calculations possible, ones, equivalents of the "*No preference*" response, were put on the diagonal. For all matrices of pairwise responses, the final hierarchy of participants' preferences was computed according to the Analytic Hierarchy Process (AHP) method proposed by Saaty [65, 66]. This computation formally involved finding the eigenvector ($\mathbf{V}_i$) and eigenvalue ($\mathbf{\Lambda}_i$) decomposition of matrix $\mathbf{PR}_i$, by solving the matrix equation $\mathbf{PR}_i \ \mathbf{V}_i = \mathbf{\Lambda}_i \ \mathbf{V}_i$. After applying the appropriate algorithm, the eigenvector ($\mathbf{v}_{i\,(\max)}$) associated with the largest eigenvalue ($\lambda_{i\,(\max)}$) approximated the weights of preferences for the investigated visual stimuli.

Finally, the vectors are standardized so that their values sum up to one. A bigger weight denotes a bigger preference of a given stimulus. Another useful feature of this technique is the possibility of verifying individuals' consistency of responses by calculating consistency ratios (CR_i). The CR values are computed for every participant based on the maximal eigen value ($\lambda_{i\,(\max)}$), the random consistency index (RI_n), which compensate for the number of compared items n, and has been experimentally determined for a given item set [65, 66]. First, the consistency index (CI_i) is derived according to formula $CI_i = \frac{\lambda_{i(\max)}-n}{n-1}$, then$CR_i = \frac{CI_i}{RI_n}$. The smaller the CR_i, the more coherent subject responses are. Values of CR_i close to one are obtained for responses generated randomly. Both preferences' vectors and CRs are used in the current study as dependent measures and analyzed in the next section.

The studies were conducted in university teaching laboratories using identical desktop computers and comparable lighting conditions. The workstations had the same computer mice and 17″ LCD monitors with a 1024 by 768 pixels resolution. A classic Microsoft Windows XP color scheme was used on all computers.

4.3 Participants

The subjects were recruited from among University of Science and Technology students. The sample included 62 males and 53 females with the youngest being 18 and the oldest 26 years old (Mean = 20.58, SME = 0.125). All subjects reported normal or corrected to normal visual acuity.

4.4 Results

Subjects' consistency ratios computed according to the AHP methodology varied from 0.0018 up to 0.06 with the mean of 0.0136 and the Standard Mean Error (SME): 0.00091.

Standard one-way Anova showed that there was no statistically significant difference in mean CR values for males and females [$F(1, 113) = 1.46$, $p = 0.23$]. Since all CRs were below the recommended by Saaty (1977, 1980) threshold of 0.1, further analyses include the data of all examined subjects.

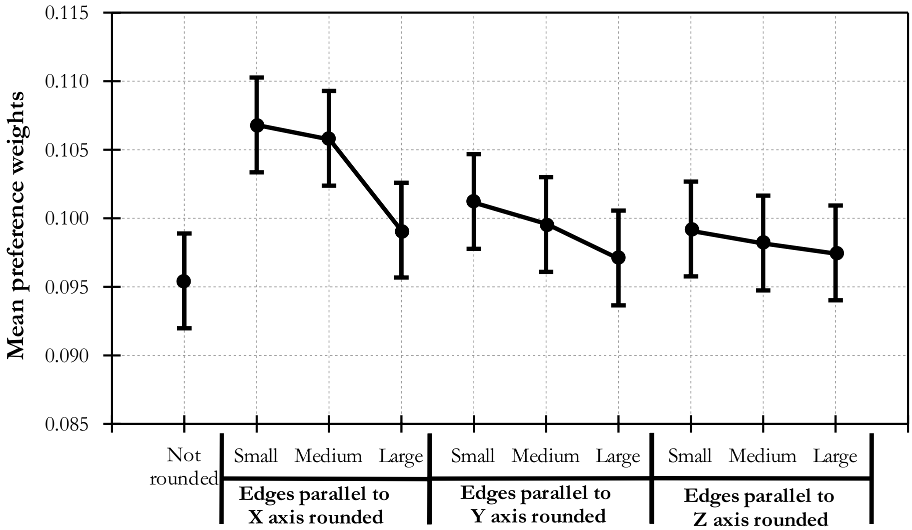


Fig. 3 Mean preference weights for all conditions in Study 1

Table 1 The basic descriptive statistics for all conditions in Study 1

Package variant			Basic descriptive statistics					
No	Roundedness axis	Roundedness degree	Mean	SME	Median	Min	Max	SD
1	None	None	0.0956	0.0024	0.0880	0.0555	0.1646	0.0258
2	Edges parallel to X	Small	0.1071	0.0019	0.1099	0.0728	0.1606	0.0208
3	Edges parallel to X	Medium	0.1062	0.0017	0.1042	0.0728	0.1595	0.0178
4	Edges parallel to X	Large	0.0996	0.0018	0.0959	0.0625	0.1600	0.0196
5	Edges parallel to Y	Small	0.1013	0.0014	0.1016	0.0624	0.1370	0.0150
6	Edges parallel to Y	Medium	0.0994	0.0013	0.0996	0.0725	0.1362	0.0139
7	Edges parallel to Y	Large	0.0970	0.0016	0.0949	0.0671	0.1414	0.0174
8	Edges parallel to Z	Small	0.0990	0.0012	0.0979	0.0701	0.1490	0.0128
9	Edges parallel to Z	Medium	0.0978	0.0019	0.0971	0.0614	0.1528	0.0205
10	Edges parallel to Z	Large	0.0970	0.0022	0.0909	0.0554	0.1567	0.0233

4.4.1 Descriptive statistics

Averaged preference weights for all conditions from Study 1 are demonstrated in Fig. 3, while basic descriptive statistics are put together in Table 1. The highest mean score was computed for the package version with small rounded edges parallel to the X axis. The classic box occurred to be the worst, however differences among the worst 8 variants were very small and, according to Fisher's LSD post hoc pairwise comparisons, almost in all cases statistically irrelevant (Table 2). The final preference hierarchy of the examined variants are given in Fig. 4.

Table 2 Fisher's LSD post hoc pairwise comparisons for all conditions in Study 1

		Not rounded	X edges rounded			Y edges rounded			Z edges rounded		
			Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
X edges rounded	Small	$< 0.0001^{***}$	×								
	Medium	$< 0.0001^{***}$	0.72	×							
	Large	0.12	0.0029^{**}	0.0088^{**}	×						
Y edges rounded	Small	0.026^{**}	0.021^{**}	0.052^{*}	0.50	×					
	Medium	0.13	0.0024^{**}	0.0075^{**}	0.96	0.46	×				
	Large	0.58	0.0001^{***}	0.0003^{***}	0.32	0.09*	0.34	×			
Z edges rounded	Small	0.18	0.0014^{**}	0.0045^{**}	0.83	0.37	0.87	0.44	×		
	Medium	0.39	0.0002^{***}	0.0009^{***}	0.48	0.17	0.52	0.76	0.63	×	
	Large	0.58	0.0001^{***}	0.0003^{***}	0.32	0.09*	0.35	0.998	0.44	0.77	×

$^{*}\alpha < 0.1$

$^{**}\alpha < 0.05$

$^{***}\alpha < 0.001$

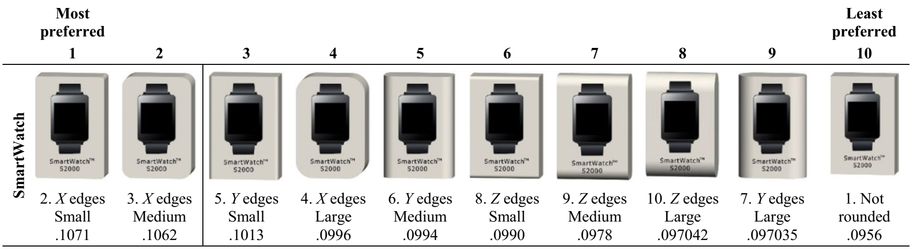


Fig. 4 Final preference hierarchy in Study 1

Analyzing the data from Table 1 and Fig. 3, a fairly clear pattern may be observed. Subjects' willingness to buy decreased along with increasing the edges' roundedness degree. Secondly, it seems that participants generally liked rounded edges along the X axis, the best rounded edges parallel to the Y axis were in the second place, while roundedness along the Z axis occurred to be the least preferred. These observations are formally verified by applying Anovas in the next subsection.

4.4.2 Analysis of variance

A formal examination of the gathered data, initially described in the previous section, was carried out by means of the standard three-way Anova. For this purpose, the experimental condition with a classic cuboid package was excluded from the analysis. Taking into account the possible association between angularity-masculinity and femininity-roundedness [23, 24], gender was also included in the analysis. The Anova results given in Table 3 revealed that Roundedness axis [$F(2, 1017)=9.7$, $p=0.0001$, $\eta^2=0.019$] and Roundedness degree [$F(2, 1017)=5.8$, $p=0.0030$, $\eta^2=0.011$] considerably influenced mean participants' weights. According to the Cohen's [18] rule of thumb (small ≈ 0.01, medium ≈ 0.06, and large ≈ 0.14), the reported values of partial eta-squares (η^2) for both significant factors indicate that their effect size was small. Although the Gender effect alone was insignificant, its interaction with Roundedness axis was meaningful [$F(2, 1017)=21$, $p<0.0001$, $\eta^2=0.039$].

Table 3 Three-way Anova results for Study 1. The influence of package *roundedness axis*, *roundedness degree*, and *gender* on mean preference weights

Effect	SS	df	MSS	F	p	η^2
Roundedness axis (RA)	0.0062	2	0.0031	90.7	0.0001*	0.019
Roundedness degree (RD)	0.0037	2	0.0019	50.8	0.0030**	0.011
Gender	0.000092	1	0.000092	0.29	0.59	
RA × RD	0.0014	4	0.00035	10.1	0.35	
RA × Gender	0.013	2	0.007	21	< 0.0001*	0.039
RD × Gender	0.00026	2	0.00013	0.41	0.66	
RA × RD × Gender	0.00076	4	0.00019	0.59	0.67	
Error	0.33	1017	0.00032			

*α < 0.0001

**α < 0.05

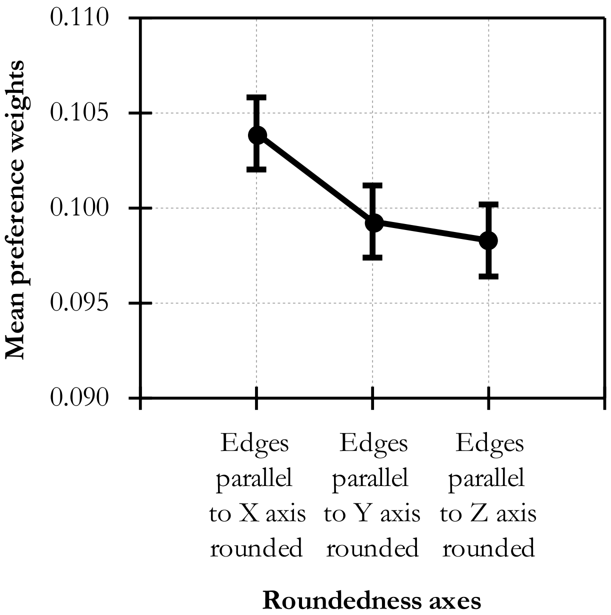


Fig. 5 Effect of *Roundedness axis* on mean preference weights [$F(2, 1017) = 9.7$, $p = 0.0001$, $\eta.^2 = 0.019$]

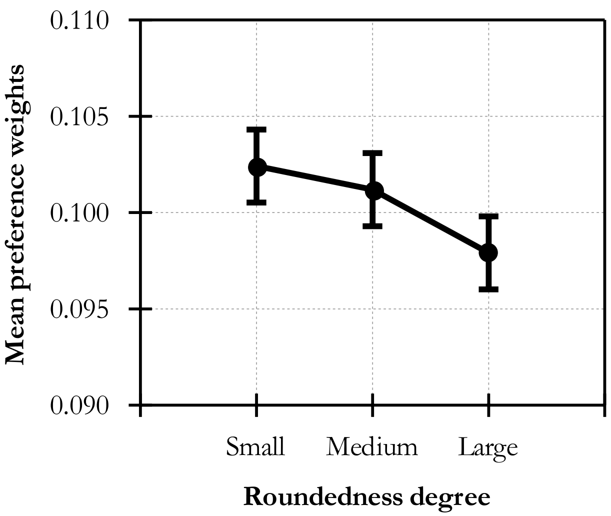


Fig. 6 Effect of *Roundedness degree* on mean preference weights [$F(2, 1017) = 5.8$, $p = 0.0030$, $\eta.^2 = 0.011$]

The graphical representation of average preference weights along with 95% confidence intervals (whiskers) for statistically meaningful effects are provided in Figs. 5, 6, and 7. In all tables presenting Anova results, the following abbreviations are used: *SS* –Sum of Squares, *MSS* – Mean Sum of Squares, *df* – degrees of freedom.

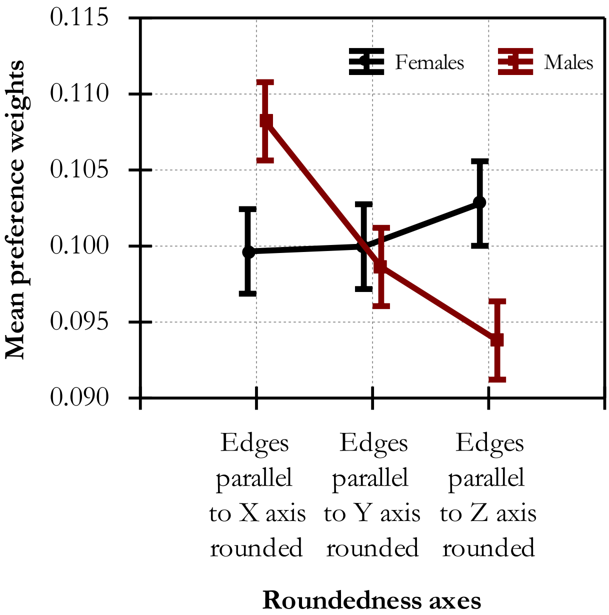


Fig. 7 Effect of *Roundedness axes*×*Gender* on mean preferences weights [$F(2, 1017)=21$, $p<0.0001$, $\eta_p^2=0.039$]

Performed Anovas formally confirm general observations based on basic descriptive statistics. Participants liked the best situation when the edges parallel to the X axis were rounded, the roundedness along the Z axis was rated the worst, while packages with Y axis edges rounded were in the middle. The post hoc Fisher's pairwise comparisons showed that the difference between Y and Z axes is statistically irrelevant ($\alpha>0.1$), whereas all other differences were significant.

Participants' purchase willingness depended almost linearly on the degree of roundedness, being the biggest for packages with small roundedness and the smallest for the most rounded versions. Moreover, for this factor, the Fisher's pairwise post hoc tests showed statistically meaningful differences ($\alpha=0.005$). Only the discrepancy between Small and Medium levels of Roundedness degree was not significant ($\alpha>0.1$).

The Gender×Roundedness axes interaction from Fig. 7 suggests that the significance of the main Roundedness axes effect was produced mainly by males. Post-hoc pairwise tests confirmed that discrepancies between Roundedness axes for women were not statistically meaningful ($\alpha>0.1$).

4.5 Discussion

The findings of Study 1 do not fully support H1. A comparison of purchase willingness rates for rounded variants with a plain box option provided unexpected results confirming only to some extent the previous psychophysiological results of better preferences for curved objects. Although, in general, the sharp package version received the lowest score, the mean preference weights for rounded objects were significantly better than for the sharp edge box only when the edges parallel to an X axis were curved slightly or medium and for the variant with small rounded Y axis edges (conditions no. 2, 3, and 5). For all remaining experimental conditions, the rounded packages did not differ significantly from the plain cuboid.

The presented Anova findings show that subjects' purchase willingness was influenced both by the axis along which the package edges were rounded as well as by the degree of applied curvature.

Data do not provide evidence supporting H2 which predicted no influence of the first factor. One of the possible explanations of favoring options with edges rounded along the X axis may be connected with the product shape presented on the frontal plane of the package. Particularly, with visible smartwatch curvatures corresponding to packages with X axis edges rounded. Some previous studies in other areas showed that people tend to rate better package attributes if they were consistent with the product. For instance, Middlestandt [51] showed that blue background color was more preferred than red for a pen, while for a bottle of mineral water and a bottle of perfume there was no difference between these colors. More evidence in this regard was reported, e.g., by Bar [3]. A similar effect could have influenced the participants' purchase willingness in the current study. In a general psychology area, one of the theories in this regard was put forward by Reber et al. [61]. Based on a review of many investigations, they claim that aesthetic preference judgments are mainly affected by processing fluency. If we assume that the higher correspondence between the packaging shape and the presented product results in better processing fluency, the present findings to some degree support the theory.

Such an explanation, however, is in contrast to the contour of the smartwatch strap visible in the picture. The smartwatch image, as a whole, rather resembles packages rounded along the Z axis than others, so subjects should favor them, which was not the case. The packages with Z axis rounded edges were among the least preferred ones, and the variant with the small rounded Y axis edges was the third best rated. What is probably even more intriguing and difficult to explain, the Roundedness axes factor was statistically meaningful only for male subjects (Fig. 7 and post hoc tests). For females, this effect was irrelevant.

Regarding the second factor, it occurs that when the degree of roundedness increases, the purchase willingness is becoming smaller and smaller, which is in contrast with H3. The effect of decreasing values of buying preferences for bigger curvatures may be partly attributed to the fact that such packages are rarely to come across in real situations or even in the virtual world of online product presentations. Unfamiliarity with such shapes in this context may have markedly diminished the positive impact of package roundedness. Such an explanation is consistent with accidentally obtained results in Bar and Neta [4], where real known objects were better rated on average than meaningless, novel shapes. This effect was also earlier reported in numerous general psychological studies. Zajonc [82] provides an extensive discussion on possible explanations based on neuroanatomical evidence of this mere-repeated-exposure phenomenon.

Another reason of the low rates for the most curved options may lie in the fact that they seem to be less physically stable than the classic box package. The solidity sensation has also been mentioned as one of the factors that may affect human preferences [58]. Bigger degrees of roundedness might have also looked as less realistic, which could have affected the customers' perception of the whole product presentation. For instance, they may not be recognized as typical product packages. The cognitive load increases as the customer comes across a nontypical situation. This, in turn, requires longer processing which, according to Reber et al. [61], may negatively affect peoples' buying preferences.

5 Study 2: Effects of package roundedness type and degree

5.1 Stimuli

Similarly to the first study, participants expressed their perceived willingness to purchase a fictitious device demonstrated on a virtual, box-shaped package. The digital packages had the same dimensions' proportions as in Study 1. The second study was complementary to the first one and dealt also with rounded edges, however, the main purpose of this investigation was to compare boxes where only edges parallel to one axis are rounded with the situation where all edges are curved. The X axis was chosen as the most popular. Thus, the first independent variable Roundedness mode was specified on two levels: (1) All edges rounded, and (2) Only sides rounded (only edges parallel to the X axis rounded).

While analyzing the results from Study 1, it occurred that packages with rounded edges parallel to the X axis were significantly better rated than other variants. Roundedness degree was investigated as the second factor. The effect was examined on four levels. Three of them were the same as in Study 1, namely, Small (radius 0.1), Medium (0.3), and Large (0.5 of a unit).

The Study 1 statistical analysis revealed that the smaller the roundedness degree, the bigger were the average weights. An additional roundedness degree was included in this study to test whether this tendency will be maintained for a considerably smaller roundedness degree. Thus, the fourth radius was set at a value twice as small as the smallest value from Study 1, that is, 0.05 of a unit, and was denoted as Tiny. A combination of these two factors provided eight different experimental conditions. All of them, along with the classical sharp package which was also included in the design, are presented in Fig. 8.

5.2 Design and procedure

A full factorial design was applied to the shape effects. Thus, subjects assessed all nine digital package variants, that is, two Roundedness types {All edges rounded, Only side edges rounded} × four Roundedness degrees {Tiny, Small, Medium, Large} together with a classic box with all sharp edges. These conditions were investigated within subjects.

The procedures applied here were identical to the one from the first study, and the same software was taken advantage of to present the stimuli and do the calculations. As there were nine different package versions, the number of necessary comparisons equal to (81—9) / 2 = 36. The studies were carried out in the same university teaching laboratories as in the first study with identical hardware and software.

5.3 Participants

The same group of 115 subjects as in the first study investigated the stimuli in Study 2.

5.4 Results

In the second study, the smallest consistency indicator amounted to 0.00222, while the highest observed value was as big as 0.0588. The average CR value equaled

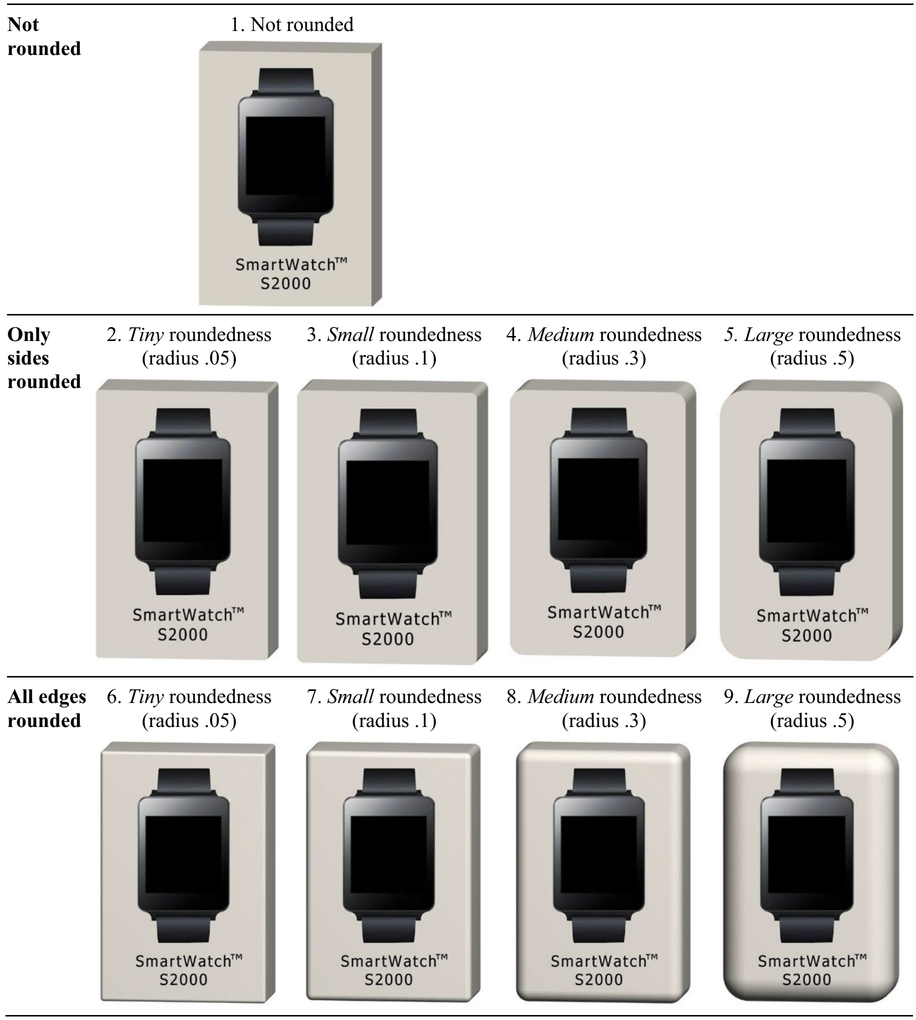


Fig. 8 All product presentation variants investigated in Study 2

0.0134 ± 0.000885 SME. One-way Anova discovered no meaningful differences in average CRs for women and men [$F(1, 113) = 0.067$, $p = 0.80$]. As all CRs were below recommended by Saaty [65, 66] threshold of 0.1, further analyses include weights computed for all examined subjects.

5.4.1 Descriptive statistics

Basic descriptive characteristics of participants' purchase willingness expressed towards all versions of the package design in the second study are provided in Table 4 and graphically presented in Fig. 9.

Table 4 The basic descriptive statistics for all experimental conditions in Study 2

Package variant			Basic descriptive statistics					
No	Roundedness type	Roundedness degree	Mean	SME	Median	Min	Max	SD
1	None	None	0.0973	0.0020	0.0926	0.0619	0.1758	0.0216
2	Only sides rounded	Tiny	0.1037	0.0016	0.0988	0.0694	0.1545	0.0176
3	Only sides rounded	Small	0.1121	0.0015	0.1091	0.0801	0.1525	0.0163
4	Only sides rounded	Medium	0.1170	0.0016	0.1129	0.0881	0.1761	0.0166
5	Only sides rounded	Large	0.1152	0.0021	0.1110	0.0770	0.1771	0.0221
6	All edges rounded	Tiny	0.1113	0.0017	0.1093	0.0710	0.1631	0.0179
7	All edges rounded	Small	0.1159	0.0015	0.1173	0.0783	0.1535	0.0158
8	All edges rounded	Medium	0.1148	0.0022	0.1128	0.0703	0.1589	0.0235
9	All edges rounded	Large	0.1128	0.0029	0.1080	0.0618	0.1779	0.0306

The most favorite option on average occurred to be the one with Only sides rounded (along axis X) to a Medium degree. On the other hand, subjects disliked the sharp edge version the most. The markedly biggest mean standard error was observed for the ninth condition. Relatively big values of SME and mean confidence intervals demonstrated in Fig. 9 may denote that the subjects' preferences were either not very distinct or were influenced by other factors. The full preference hierarchy obtained by ordering weights is demonstrated in Fig. 10.

Given the data from Figs. 9 and 10, one may notice that packages with all edges rounded seem to be generally better assessed than those with only side edges rounded. It is hard to tell whether there is any clear pattern concerned with the applied roundedness degree, as there are considerable variations between individual conditions. However, the data suggest that there may exist a type of optimal amount of roundedness as the medium rounded variant was the best in the group where only sides were rounded, while for All edges rounded condition, the smaller roundedness degree was preferred (compare Fig. 9). Fisher's LSD post hoc pairwise comparisons were used to formally verify differences between conditions' mean weights. The results are put together in Table 5.

According to them, both the classic box package and its tiny rounded along one side version were markedly worse (at least at a level of 0.05) than all other versions. The data also show that there is a quite clear tendency of increasing purchase intentions for bigger roundedness degree when options with only sides rounded are concerned. In this case, Tiny roundedness is significantly better than no roundedness, *Small* is better than *Tiny*, and *Medium* receives higher rates than Small roundedness. There is, however, no meaningful difference between *Medium* and *Large*. Among variants where all sides were rounded, the only statistically significant ($\alpha = 0.1$) difference was observed between *Tiny* and *Small* roundedness levels.

Analyzing the data in Table 5 along with the final preference hierarchy given in Fig. 10, it could be seen that among the first best-rated variants the differences are insignificant. Moreover, the variants either with sharp or Tiny rounded edges are decidedly worse than other options. Further formal statistical analyses are provided in the next subsection.

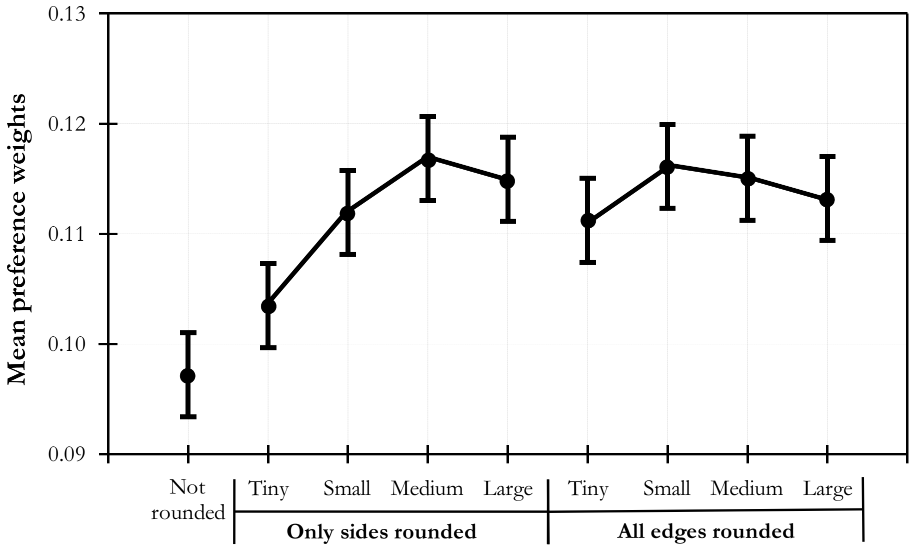


Fig. 9 Mean preference weights for all conditions in Study 2

5.4.2 Analysis of variance (Anova)

A standard three-way analysis of variance was employed to formally verify the differences between the analyzed effects. A classic cuboid package was not included in this analysis. The first factor grouped presentations with either only side edges rounded (symmetry along X axis) or boxes having all edges rounded. The second factor differentiated presentations by the degree of roundedness (*Tiny*, *Small*, *Medium*, and *Large*). *Gender* was included as the additional third factor. Anova outcomes provided in Table 6 show no statistical significance of the *Roundedness type* effect. The second factor was statistically significant [$F(3, 896) = 7.7$, $p < 0.0001$, $\eta^2 = 0.025$]. Applying the Cohen's [18] rule of thumb, the size effect of this factor can be classified as small.

The Roundedness degree effect is illustrated in Fig. 11.

Additional Fisher's LSD post hoc pairwise comparisons were performed to see whether there were any differences between levels. These results, put together in Table 7, revealed that the Tiny roundedness degree was decidedly worse than all other factor levels.

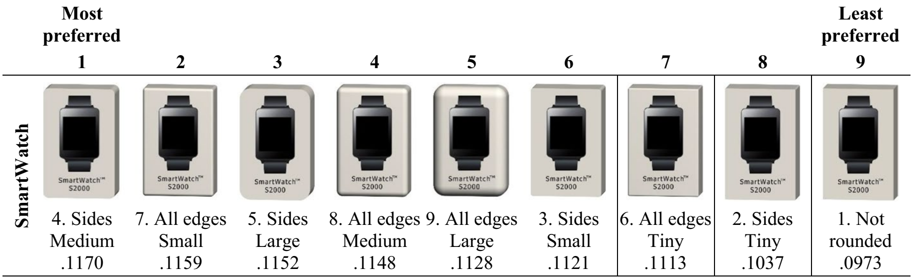


Fig. 10 Final preference hierarchy in Study 2

Table 5 Fisher's LSD post hoc pairwise comparisons for all conditions in Study 2

		Not rounded	Only sides rounded				All edges rounded			
			Tiny	Small	Medium	Large	Tiny	Small	Medium	Large
Only sides rounded	Tiny	0.019**	×							
	Small	< 0.0001***	0.0024**	×						
	Medium	< 0.0001***	< 0.0001***	0.073*	×					
	Large	< 0.0001***	< 0.0001***	0.25	0.53	×				
All edges rounded	Tiny	< 0.0001***	0.0057	0.79	0.039**	0.15	×			
	Small	< 0.0001***	< 0.0001***	0.17	0.69	0.82	0.097*	×		
	Medium	< 0.0001***	< 0.0001***	0.32	0.43	0.87	0.20	0.70	×	
	Large	< 0.0001***	0.001**	0.79	0.13	0.37	0.59	0.26	0.46	×

*$\alpha < 0.1$

**$\alpha < 0.05$

***$\alpha < 0.001$

Table 6 Three-way Anova results for Study 2. The influence of package *Roundedness type*, *Roundedness degree*, and *Gender* on mean preference weights

Effect	SS	df	MSS	F	p	η^2
Roundedness type (RT)	0.0010	1	0.0010	20.4	0.12	
Roundedness degree (RD)	0.0097	3	0.0032	70.7	<0.0001**	0.025
Gender	0.000011	1	0.000011	0.027	0.87	
RT×RD	0.0037	3	0.0012	30.0	0.031*	0.0098
RT×Gender	0.0052	1	0.0052	12	0.0004**	0.014
RD×Gender	0.0012	3	0.00040	0.94	0.42	
RT×RD×Gender	0.0012	3	0.00038	0.92	0.43	
Error	0.38	896	0.00042			

*$\alpha < 0.05$

**$\alpha < 0.005$

The Anova also presents the existence of two significant interactions: *Roundedness type*×*Roundedness degree* [$F(3, 896) = 3.0$, $p = 0.031$, $\eta^2 = 0.0098$] and *Roundedness type*×*Gender* [$F(1, 896) = 12$, $p = 0.0004$, $\eta^2 = 0.014$]. The first one, demonstrated in Fig. 12, suggests that subjects preferred packages with all rounded edges when the *Roundedness degree* was *Small.*

For boxes with only sides rounded (symmetry along *X* axis), *Medium* or even *Large* roundedness degrees were better perceived. The second interaction (Fig. 13) showed that men liked more conditions with only sides rounded whereas females quite the opposite – markedly favored options with all edges rounded.

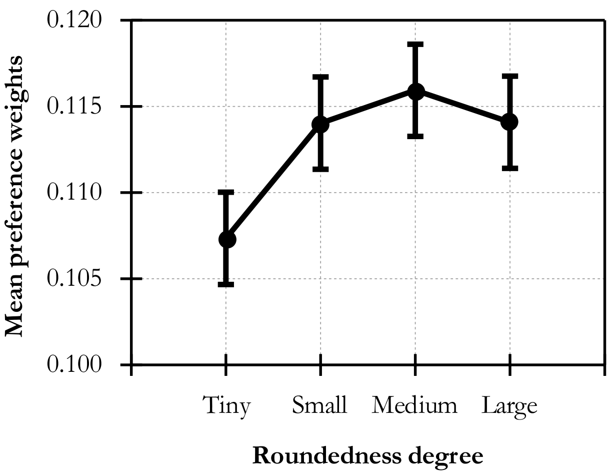


Fig. 11 Effect of *Roundedness degree* on mean preference weights in Study 2. [$F(3, 896) = 70.7$, $p < 0.0001$, $\eta.^2 = 0.025$]

Table 7 Fisher's LSD post hoc pairwise comparisons for the *Roundedness degree* effect in Study 2

	Tiny	Small	Medium	Large
Small	0.0008*	×		
Medium	< 0.0001*	0.32	×	
Large	0.0007*	0.98	0.33	×

*α < 0.001

5.5 Discussion

In this follow-up study, the roundedness effect was further explored to see whether curving all edges of the package box would result in higher purchase willingness than in the case where edges only along the axis *X* are rounded (the best from the first study).

Generally, all rounded shapes were perceived better than the sharp version. This is consistent with the results from the first study where Small and Medium conditions rounded along the *X* axis were meaningfully better than the classical cuboid. In this respect, the findings confirm H1.

The data analysis indicates that there are differences in perceiving variants with all edges rounded and those curved only along the *X* axis. This is again in contrast to H2 where no impact of rounding specific axes was expected. Based on the literature review, one could conclude that more roundedness transforms to bigger buying preferences. However, if one takes into account the *Roundedness degree* results and the *Roundedness type* × *Roundedness degree* interaction, the picture seems not to be so clear.

The decreasing trends concerned with the Roundedness degree effect for *Small*, *Medium*, and *Large* options (Fig. 9) obtained for boxes with all edges rounded visually follow the patterns from Study 1 (Figs. 3 and 6), however the differences are statistically irrelevant. Only the Tiny version in this case was significantly less rated than the mean scores for the Small option. This suggests that although *Tiny* roundedness is much better than the

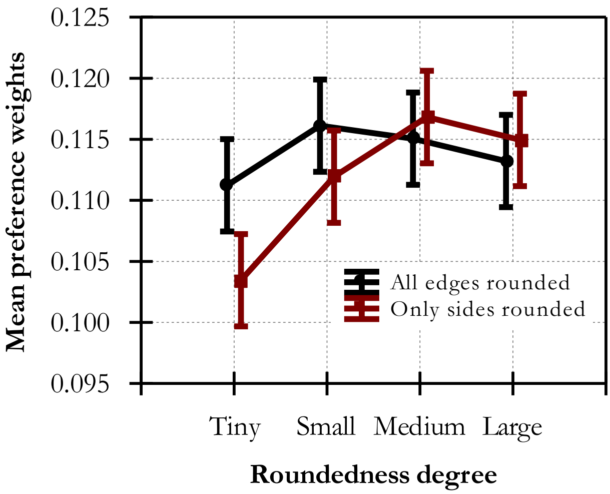
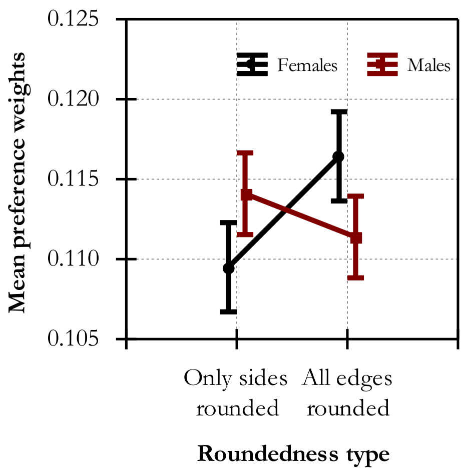


Fig. 12 Effect of *Roundedness type* × *Roundedness degree* interaction on mean preference weights in Study 2. [$F(3, 896) = 30.0$, $p = 0.031$, $\eta.^2 = 0.0098$]

Fig. 13 Effect of *Roundedness type* × *Gender* interaction on mean preference weights in Study 2. [$F(1, 896) = 12$, $p = 0.0004$, $\eta.^2 = 0.014$]



sharp edge box yet worse than the *Small* version. Similar relation may be noticed for boxes rounded along one axis, however in this event, *Medium* is better than *Small* ($\alpha < 0.1$) and seems to constitute a kind of optimum. These outcomes and the visual analysis of Figs. 9, 11, and 12 rather do not provide evidence for supporting H3, which assumed a positive and linear relationship between bigger degrees of roundedness and purchase willingness.

The different results obtained in the first and second studies are probably caused by changing the context of comparisons. It is widely acknowledged in the psychological literature that preferences may be strongly influenced by conditions accompanying the examination. As compared to the previous examination, another Tiny roundedness degree level was included and a qualitatively different factor was added. It occurred that the one axis (single axis symmetry) versus all edges rounded factor probably had an impact on subjects' perception. A similar disturbing influence might be attributed to the additional level of *Roundedness degree*.

The visual inspection of data regarding the Roundedness degree (Fig. 9) suggests that there probably exists an optimal value of this feature since the *Tiny* rounded edges were on average worse than their *Small* rounded counterparts. The statistically significant interaction of *Roundedness type* × *Roundedness degree* additionally supports the conjecture of optimal amount of roundedness. The *Roundedness type* × *Gender* interaction revealed that females markedly more preferred package variants with all edges rounded. The effect of liking more rounded shapes by women is consisted with studies showing associations between femininity and curved contours [23, 24].

6 General discussion

6.1 Theoretical contributions

A number of past studies have tested curved versus angular shape effects in various contexts, however it is unclear if the findings apply also to customers' purchase willingness for packages presented digitally. The current study fills this gap by partly confirming the better perception of some of the examined curved shapes as compared to a standard edgy cuboid.

These data also reveal that the roundedness effect may be irrelevant to purchase willingness depending on other investigated factors.

Apart from verifying the knowledge in a very specific context, the research contributes to the existing literature by providing additional insight about the influence of packaging features related to symmetry that were earlier not examined in such detail. Data from Study 1 show that purchase willingness of rounded packages decreases while increasing the degree of roundedness, whereas findings from Study 2 suggest that there probably exists optimum “amount” of the roundedness that positively influences consumers’ perception and purchasing willingness.

This research investigates a potentially important and, it seems that yet not reported, impact of the axis along which the packaging edges are rounded on buying willingness. It was identified that purchase willingness was considerably higher when edges parallel to the *X*-axis were rounded as compared with rounding along other axes. This phenomenon was observed only for male participants.

6.2 Practical implications and applications in technological solutions

Besides the contributions presented above, the results of this study provide valuable information for practitioners on how digital product presentations influence perception and purchase willingness. From this point of view, effective product digital demonstrations are crucial in today’s world, where they are ubiquitous, and people often make purchasing decisions based solely on them.

The outcomes revealed here can serve as direct guidelines for computer graphics designers, who are preparing the visual appearance of products or their packaging. These recommendations can be applied to anything from two-dimensional projects to three dimensional models, animations, and virtual reality experiences or interactive product demonstrations. For example, designers can use these guidelines to visualize and display goods or services in electronic shops, banners for websites or advertisements demonstrated in outdoor digital billboards, video walls or smaller screens placed in elevators, corridors, supermarkets, and other settings. The possible applications are also important for designing and creating marketing content in various multimedia systems and platforms, such as video on-demand, interactive TV, network kiosk systems or personalized electronic journals. It is worth noting that even simple and relatively inexpensive changes to product displays can result in increased sales.

In addition to the above-mentioned applications in classic two-dimensional environments, these findings can also be applied to technology solutions or multimedia tools for three-dimensional modeling and rendering. For example, by creating three-dimensional product packaging, designers can showcase the curved shapes and axes of curvature in a more realistic and visually appealing manner. Another possibility is to use augmented or virtual reality technologies, which can provide customers with a more immersive experience, allowing them to interact with the product packaging and visualize the rounded edges in real-time. Furthermore, incorporating haptic feedback can enhance a customer’s perception of the designed packaging enabling them to feel the difference in roundedness between parts of the packaging design. Moreover, incorporating interactive elements in different multimedia technology solutions can facilitate manipulating and exploring the product packaging design, providing a more engaging experience. This, in turn, allows customers to better understand and appreciate the curved shapes. For example, a potential user could drag their finger along the surface of the packaging design, causing it to rotate and reveal different angles and curves.

On the other hand, digital product presentation requires the use of technology to communicate and demonstrate product features. The study results presented provide valuable insights into user or customer behaviors, needs, preferences, and expectations. Thanks to this, technology solution providers can create multimedia software and hardware tools that are intuitive, engaging, and effective themselves. These findings can also be used to develop analytics tools and applications that offer content creators and marketers detailed information about how users interact with their content. By closely monitoring customer preferences, companies can ensure that their technology solutions remain relevant and effective in meeting the needs of their target audience.

6.3 Limitations and future research

As usually, in experimental investigations, a number of various limitations need to be taken into account while drawing conclusions. One should be aware that the examined subjects are coming from a specific and very homogenous population: there were almost only young white students living within a single cultural society. Naturally, they may not be representative of the general population as they possibly differ in education, habits, values, attitudes towards technological innovations, or electronic novelties. In spite of this obvious limitation, the examined group seems to be a big potential target. Nevertheless, to generalize the obtained outcomes to a broader group of target consumers, this paper studies should be replicated on subjects from other populations.

Although experimental forced choice-based methodologies can be highly correlated with actual purchase decisions [12], it is not clear to what extent the declared purchase willingness will translate to real buying situations, all the more that the current findings are based on a fully controlled study conducted in an artificial laboratory environment. The presented research results would undoubtedly gain much of their theoretical and practical importance and validity if the subsequent research confirms the study results in more ecological situations.

One should also be cautious in generalizing the presented outcomes to markedly different products, especially those belonging to different than the higher involvement class. As it has been shown in some papers cited in the literature review, the observed effects may change if a desired attribute of the presented product will be directly related with potency or strength (e.g., energy drinks, or vacuum cleaners) since these features are usually associated with sharp edges. The research direction including different classes of products naturally deserves further exploration. There is also an interesting question whether subjects are making different inferences about the product depending on its packaging form.

The obtained results could have also been moderated by individual-specific differences. Although the gender effect was included in the analyses, one should bear in mind that women from a technology-oriented university might not be representative of the whole female population. Thus, in future studies, apart from fully controlling the gender factor and choosing a more representative sample, one may incorporate the effect of subjects' degree of femininity and masculinity measured, for instance, by the Franck and Rosen [23] test. Moreover, in light of the results showing that people with a high sensitivity to design like more rounded contours [7], next experiments might also verify if this factor applies in the current study context.

Another important consideration is concerned with the applied method of eliciting relative preferences by means of pairwise comparisons. Although, such a technique provides more accurate results than other approaches [40], it, unfortunately, highly restricts the possible number of examined factors and their levels in a particular experiment. In addition, the scope of a single study was also limited by a decision to apply a full factorial design meant for exploring the effects' interactions. As the interactions were not always identified in the present research, future designs may be based on a fractional factorial approach which would facilitate analyses of more effects in a single study.

This paper focuses on still image digital presentations. However, a number of studies have shown that dynamic visualization of product information in the form of videos or animations can significantly influence and shape customer purchasing behavior and preferences (compare, e.g., [15, 31, 64]). Thus, future research should also examine the influence of roundedness features of product packaging in dynamic visualizations. Moreover, it would be very interesting to incorporate the graphical features examined in the present study into investigations involving virtual and augmented reality, which have experienced rapid development recently.

7 Conclusions

Generally, the current research presents some empirical evidence on how a variety of digital forms of product presentation involving various features influences the purchase willingness of potential buyers. The present investigation tries to add some more insights into this problem by experimentally analyzing such aspects of product packaging as various roundedness degrees and roundedness axes.

Multimedia tools play a critical role in the creation, editing, and sharing of digital product presentations. By leveraging multimedia techniques and systems effectively and taking advantage of relevant study results on digital information visualization, marketers and designers can create informative, and compelling product presentations that showcase the value and benefits of their products.

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Data availability Data will be made available on reasonable request.

Declarations

Conflict of Interest The author states that there is no conflict of interest.

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