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Perceiving Intersensory and Emotional Qualities of Everyday Objects: A Study on Smoothness or Sharpness Features with Line Drawings by Designers

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Abstract

A large number of studies have focused on the aesthetic value of smoothly curved objects. By contrast, angular shapes tend to be associated with tertiary qualities such as threat, hardness, loudness, nervousness, etc. The present study focuses on the effect of curvilinearity vs angularity on the aesthetic experience of design artefacts. We used the drawings of everyday objects with novel shapes created by 56 designers (IUAV image dataset). Each drawing had two versions: a smooth and an angular version. To test new tertiary associations, beyond aesthetic value, we obtained ratings for seven characteristics ('soft/hard, sad/cheerful, male/female, bad/good, aggressive/peaceful, agitated/serene, useless/useful') from 174 naïve observers. Importantly, each naïve rater saw only one of the two versions of an object. The results confirmed a significant relation between smoothness and hardness as well as other (tertiary) associations. The link between smoothness and usefulness confirms that perceptual utility is significantly influenced by the shape of the object. This finding suggests that tertiary qualities convey both static and functional information about design objects. The role of perceptual constraints in drawing design artefacts is also discussed.

Keywords

angular shape, design drawings, product design, smooth shape, tertiary qualities

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1. Introduction

The user's aesthetic perceptual experience is considered fundamental in design. Many studies have demonstrated the effect of perceptual features on the impact and use of design products (Batra *et al.*, 2000; Crilly *et al.*, 2004, Green and Jordan, 2002; Jordan, 2000; Norman 2013). The effect can be on the aesthetic feeling of the product (Crozier, 1994; Hassenzahl, 2008; Hekkert, 2006; Monö, 1997; Petrelli *et al.*, 2016; Soranzo *et al.*, 2018), but also on the consumer preference (Bloch, 1995; Westerman *et al.*, 2012), and even on the perception of usability (Kurosu and Kashimura,1995; Mugge and Schoormans, 2012; Tractinsky *et al.*, 2000).

In this study we used drawings of design products that differed on their curvature/angularity. In a previous study we had confirmed that the curved products were seen as having more positive association (Bertamini and Sinico, 2019). Here we test new tertiary associations, including the degree of perceived usefulness of these objects.

Several design studies have proposed generative models for the exploration of product aesthetic shapes (Alcaide-Marzal *et al.*, 2020; Bernal *et al.*, 2015; Hyun and Lee, 2018). Visual appearance is considered the primary step in the design aesthetic process. For example, Kansei engineering, developed by Nagamachi (1997; Nagamachi and Lokman, 2011), is focused on the identification of product appearances for the design characteristics. Claiming that visual appearance is a crucial attribute of product design, Crilly *et al.* have stated: "measuring consumer response to products and correlating perceptions with product features may offer the opportunity to modify designs and closer align them with consumers' aesthetic preferences" (2004, p. 559). The current study investigated the relation between smooth or angular objects and tertiary properties, such as intersensory or emotional qualities.

1.1. Preference for Smooth Curvature

There is strong evidence from the psychological literature that formal properties of the stimuli, such as symmetry, have universal effects on visual preference (Latto, 1995; McManus, 1980; Ramachandran and Hirstein, 1999). Some studies have found a robust effect of visual preference for curvature as opposed to angularity. Apart from the many cases of preference for smooth curvature and curved lines in visual art (Bertamini and Palumbo, 2014), recent studies have investigated more detailed aspects of preference for curvature (Palumbo *et al.*, 2015; Bertamini *et al.*, 2016, 2019). Bar and Neta (2006) have found a preference for images of objects with rounded contours using everyday objects such as wristwatches or sofas. This result has been explained by postulating an adaptive fear response. To support this, Bar and Neta have also measured activation in the amygdala, a brain area involved in processing fear, using

functional imaging (fMRI; Bar and Neta, 2007). They confirmed a stronger bilateral activation of the amygdala for sharp-angled shapes compared to curved shapes.

Silvia and Barona (2009) found preference for curvature using simple regular and irregular polygons. They noticed that individual differences in expertise in the arts moderated the effect of curvature on preference. Studying car design, and focusing on the evolution of the popular forms in the later part of the 20th century, Leder and Carbon (2005) have found that curved interiors are perceived as more attractive. Studying architectural spaces, Vartanian *et al.* (2019) compared experts (self-identified architects and designers), and non-experts on preference for curvature. Results show that experts found curvilinear spaces more beautiful than rectilinear spaces, whereas curvilinear spaces had no influence on beauty judgements among non-experts. However, non-experts preferred to enter in curvilinear spaces than in rectilinear ones. Recently, Cotter *et al.* (2017) found that individuals experienced in arts show a greater preference for curvature of irregular polygons. Gómez-Puerto *et al.* (2018) have supported the universality of a preference for curvature by cross-cultural comparisons. However, a recent study failed to replicate the effect of curvature in Japan (Maezawa *et al.*, 2020). Studying the aesthetic preference for mobile devices design, Ho *et al.* (2016) found a correlation between curvature perception and product size. Observers perceive a lower curvature in bigger objects than in smaller objects. In addition, they found that observers without a design background were more influenced by particular features, such as angularity, than experts.

A significant link between smoothness and beauty is confirmed also by Bertamini and Sinico (2019). This study explored the effect of curvature in relation to other dimensions. It tested the relationship between seven different categories (ugly/beautiful, dark/light, complex/simple, heavy/light, old/modern, dangerous/safe, asymmetry/symmetry) and the curvilinearity/angularity factor in drawings of everyday products. Using objects in two versions, rounded and angular, Bertamini and Sinico found that smooth shapes have been perceived as more beautiful, but also less dangerous, more asymmetrical, and lighter.

1.2. Angularity vs Curvature in Intersensory and Emotional Perception

Some studies on the dichotomy between angularity or curvature have tested the perceptual intersensory properties of design artefacts (Ghoshal *et al.*, 2000). It has been demonstrated, for example, that smooth shapes and smooth typefaces are more associated with sweet tastes, where angular shapes and angular typefaces are more linked with sour tastes (Velasco *et al.*, 2014). Other studies oriented to intersensory perception have shown an influence of the containers on

the taste of yogurt. The yogurt with angular container was perceived as more intense (Becker *et al.*, 2011). Using six design products (table lamp, toaster, hanger, candle, teapot, floor rug, and jug), either angular or curved, Ghoshal *et al.* (2000) asked the participants to give an evaluation on different categories including hedonic attributes (fun/not, exciting/not, delightful/not, enjoyable/not) and utility or function (effective/not, helpful/ not, functional/not, practical/not). The results demonstrated that the value of hedonic perception was higher for design products with curved shapes, and the value of functional perception was higher with angular shapes.

The role of curvature in relation to intersensory perception was remarked by the early Gestalt School of psychology. The well-known 'takete/maluma' demonstration is about curved and angular shapes (Köhler, 1929/1947). Observers are asked to associate two meaningless words, 'takete' and 'maluma', with two shapes they had never seen before, one angular and one rounded. Tha angular is generally labelled takete and the rounded one maluma. This association is based on similarity of intersensory features, as confirmed by later studies (e.g., Kwok *et al.*, 2018; Milan *et al.*, 2013). It should be stressed that we do not use the term association as it was used by Associationists and Empiricists, or by Fechner (see Ortlieb *et al.*, 2020) which is a derivation of the former. We use the term association as evidence of the immediate perceptual correspondence between superordinate qualities.

For this kind of phenomena, Gestalt psychologists adopted the terms 'tertiary qualities', 'physiognomic characters', 'way of being' (*"Wesenseigenschaten"*) or 'expressive qualities' (Arnheim, 1964; Köhler, 1938; Koffka, 1935; Metzger, 1963). In particular, they used the term tertiary, recalling the traditional classification by Locke (2008 [1690]), to accentuate the irreducibility to the physical and physiological dimensions of tertiary qualities compared with primary and secondary qualities (Bozzi, 1999; Sinico, 2012). In this context, tertiary qualities denote qualities of immediate perception that are not directly measurable with physical instruments (unlike primary qualities such as shape, size, number, etc.), or with physiological instruments (unlike secondary qualities such as colour, sound, taste, etc.), but are anyhow intersubjective (e.g., visual lightness, colour hotness, or a happy landscape). Tertiary qualities are indirectly measurable with psychophysical methods insofar as they are non-reductive emergent properties on the basis of primary and secondary qualities (Sinico, 2015). Tertiary qualities typically concern intersensory and emotional perception.

Because tertiary qualities convey intersensory and emotional values, they have been included within aesthetic theories by Bosanquet (1892) and Alexander (1933). Unlike these authors, whose perspective maintained that tertiary qualities are originated within the individual perceiver, Gestalt

psychologists claimed that tertiary qualities can be independent of the perceiver, insofar besides the subjective private perception, there is a general shared intersubjective quality. Arnheim adopted tertiary qualities theory to describe the expressive dynamic in pictorial art (1974). Every image can be analyzed on the basis of tertiary qualities that express meaning directly, without cross-reference. We also use the term expressive quality for a tertiary quality that expresses something, provides meaning or emotion, because of its own perceptual properties.

Other studies have investigated how intersensory perception affects design products. For example, the correspondence between curvilinear or angular shapes and tastes, flavours, and the oral somatosensory attributes of foods and beverages has been highlighted (Spence, 2012). Adopting Köhler's categories 'takete' and 'maluma', Ngo *et al.* (2011) demonstrated a relationship between angularity of visually presented shapes and the bitterness of chocolate. When the cocoa content in the chocolate samples increased, the participants tended to associate the taste of the commercially-produced chocolate with the word 'takete' and the angular shape (Ngo *et al.*, 2011). Likewise, the oral somatosensory carbonation (sparkling water) was associated with angular shapes, while still water was associated with rounded shapes (Chandrashekar *et al.*, 2009). The same associations are found also with emotional characters. The angular shaped figure is clever, tall, small, slim, nervous, nasty, upper class, masculine, and tendentially happy (Milan *et al.*, 2013). Several studies have been focused on the evidence that shapes with angular lines are considered more threatening than shapes composed of curved lines (Aronoff *et al*., 1988, 1992; Bar and Neta, 2006). Furthermore, people associate angular shapes with aggression and round shapes with peacefulness (Lindauer, 1990). Using abstract shapes drawn by naïve people, Sievers *et al.* (2019) found that excitation and angry associations increase with the number of corners, while sadness and peacefulness decrease with the number of corners.

The stimuli for the present study were created by a group of junior designers. We asked Master's students to draw everyday objects and to make two versions of each object, one rounded and one angular. There is a wide literature which describes the process of drawing as a stage of designing (Cross, 2001; Dinar *et al.* 2015; Mao *et al.*, 2020; van der Lugt, 2005) and ideation (Do *et al.*, 2000; Goel, 1995; Schon and Wiggins, 1992; Suwa and Tversky, 1997). Our goal was to explore the presence of perceptual constraints in drawing design artefacts and to measure the users' responses, including the shared and private variance in order to verify the subjective dimension of the expressive quality. In total, we created a database of 772 pairs of objects, and the images are available on *Open Science Framework* (https://osf.io/cx62j/). Further details are described in Bertamini and Sinico (2019).

2. Method

2.1. Image Generation

The images were drawn by 56 young designers (25 males, 31 females), aged 22 to 27 years. They were reading for a Master's degree in Product and Visual Communication Design in the Department of Architecture and Arts at the IUAV University of Venice and were enrolled in a course on Human Factors.

Each designer was asked to produce images of seven different objects, each one in two versions: curved ("*arrotondato*") and angular ("*spigoloso*"). The images were drawn on a separate A4 page and afterwards were scanned and scaled (Fig. 1). Two authors produced only five pairs of objects and two more created six pairs. As a consequence, we totally obtained 772 images (386 angular and 386 smooth). Of the 772 images, 174 were drawn with a computer and 598 were drawn freehand. Designers were free to choose the artefact. We did not focus on the distinctive type of objects, in the analyses we consider effects across subjects and across objects but we expect these to be consistent.

The images are available on Open Science Framework (https://osf.io/cx62j/). In the data set, the following information is included: author (a unique numerical identifier of the creator), type (smooth and angular), example (a unique numerical identifier of the drawing), object (a label, such as 'chair'), a category for the type of drawing (computer-generated or freehand), the sex of the author, and the presence or absence of shading in the drawing. In addition, we list file size (in bytes) and the ratio between compressed and uncompressed file (jpeg ratio). Compression ratio has been used in the literature as a measure of image complexity (Forsythe *et al.*, 2008; Palumbo *et al.*, 2014).

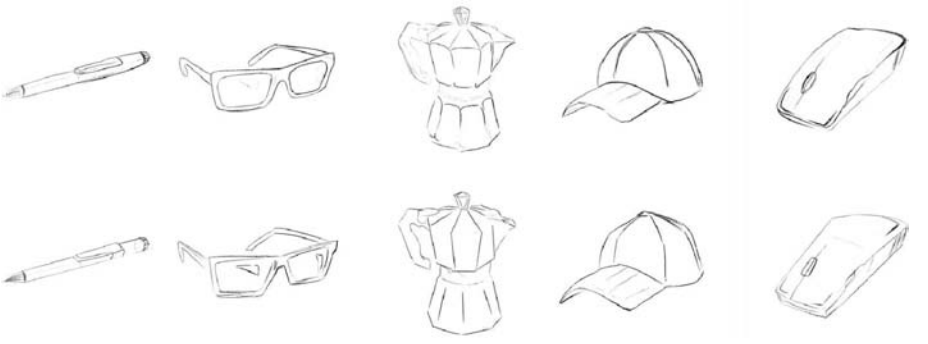

Figure 1. Examples of images. The top row shows the smooth version and the bottom row shows the angular version.

2.2. Image Rating

2.2.1. Participants

The participants consisted of 84 volunteers (42 females and 42 males), ranging in age from 18 years to 68 years. A similar procedure was used with different categories in a previous study. None of the current participants took part in the previous study (Bertamini and Sinico, 2019) and none were involved in the creation of the images. The experiment had approval from the IUAV Research Ethics Committee.

2.2.2. Design

Every observer saw 25 images of 25 *different* items.; that is, every observer could not see the same item in both versions (angular and smooth) of the Type variable. Before the beginning of the experiment, the same ten images were used for a practice session for all the participants. All aspects of the procedure were similar to those in a previous study (Bertamini and Sinico, 2019). The responses to the practice were not included in the analysis. The data have been obtained from 84 observers divided in 14 groups. Each group saw a different set of 25 images and therefore we were able to collect data for 350 images. Because for each image we have two versions, the items tested were 175.

2.2.3. Procedure

The presentation of the stimuli was conducted under computer control, with a program in Python using the PsychoPy software (Peirce, 2007) that randomized and arranged the order of stimuli, presented them on the monitor, and recorded the subject's responses. The trials and the categories were presented to each participant in an individually randomized order. Distance from the screen was at a natural distance of approximately 57 cm; all stimuli were 10° of visual angle in height. An analogue scale was placed under the stimuli (Fig. 2). Participants indicated the degree of the value of the object and responded using the mouse. The direction of the rating scale was varied randomly. Therefore, there were two possible directions, the original one (e.g., 'hard' on the left) and the reversed one ('hard' on the right).

The seven rating scales were: hardness (soft/hard), sadness (sad/cheerful), gender (male/female), goodness (bad/good), peacefulness (aggressive/peaceful), serenity (agitated/serene), usefulness (useless/useful). These categories were chosen because they include the principal expressive qualities domains: intersensorial, emotional, moral; humoral; genderless; interpersonal attitude; instrumental. The words used in Italian were: "*morbido/duro, triste/allegro, maschile/femminile, cattivo/buono, aggressivo/pacifico, agitato/calm, inutile/utile*", respectively. Note that for the goodness scale the Italian words have a specific moral/behavioural connotation and are therefore less broad in meaning than the English terms.

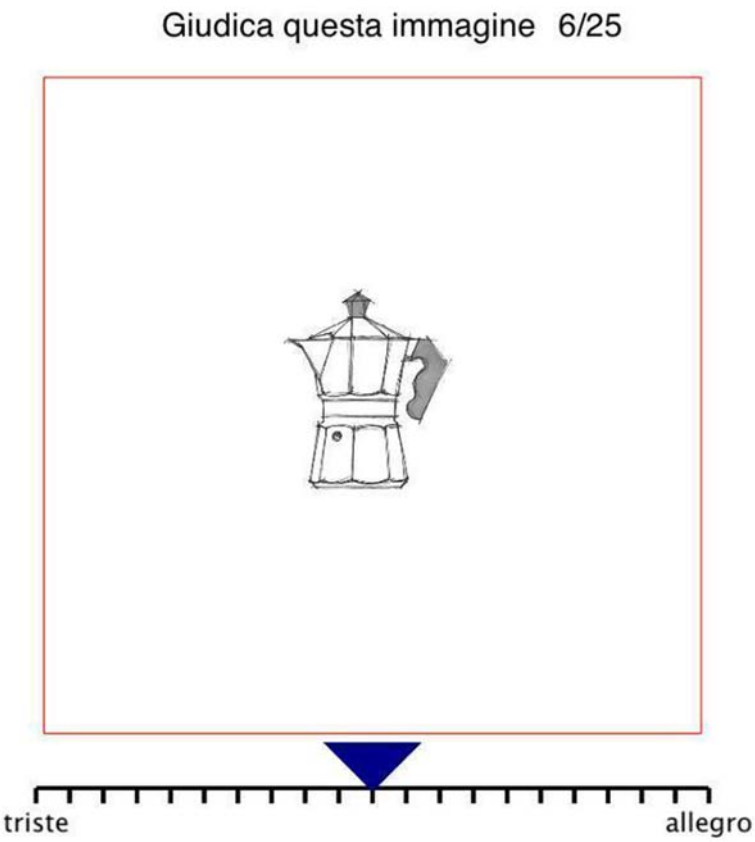

Figure 2. An illustration of the task showing a rating scale for sadness. The two extremes of the scale are "triste" ('sad') and "allegro" ('cheerful'). The triangular marker was always shown in the centre of the scale at the starting point. The sentence at the top of the screen says: "please judge this image 6/25". This number informed participants of how many images have been seen out of the total number of images.

2.2.4. Analysis

We performed seven mixed ANOVAs, one per each dependent variable, using the following design. The dependent variables were: hardness (soft/hard), sadness (sad/cheerful), gender (male/female), goodness (bad/good), peacefulness (aggressive/peaceful), serenity (agitated/serene), usefulness (useless/useful). The within-subjects factors were Type (smooth/angular), and Direction (original/reversed). The between-subjects factor was Gender (Fig. 3). The factor Direction concerns the positions (right/left) in which the poles of the rating scales were randomly displayed. The rating score ranged between −10 and 10. Therefore, for example, when the label soft was on the left (original direction) the highest possible score for soft was −10 and the highest possible score for hard was 10. Although the labels were presented in two directions, for the

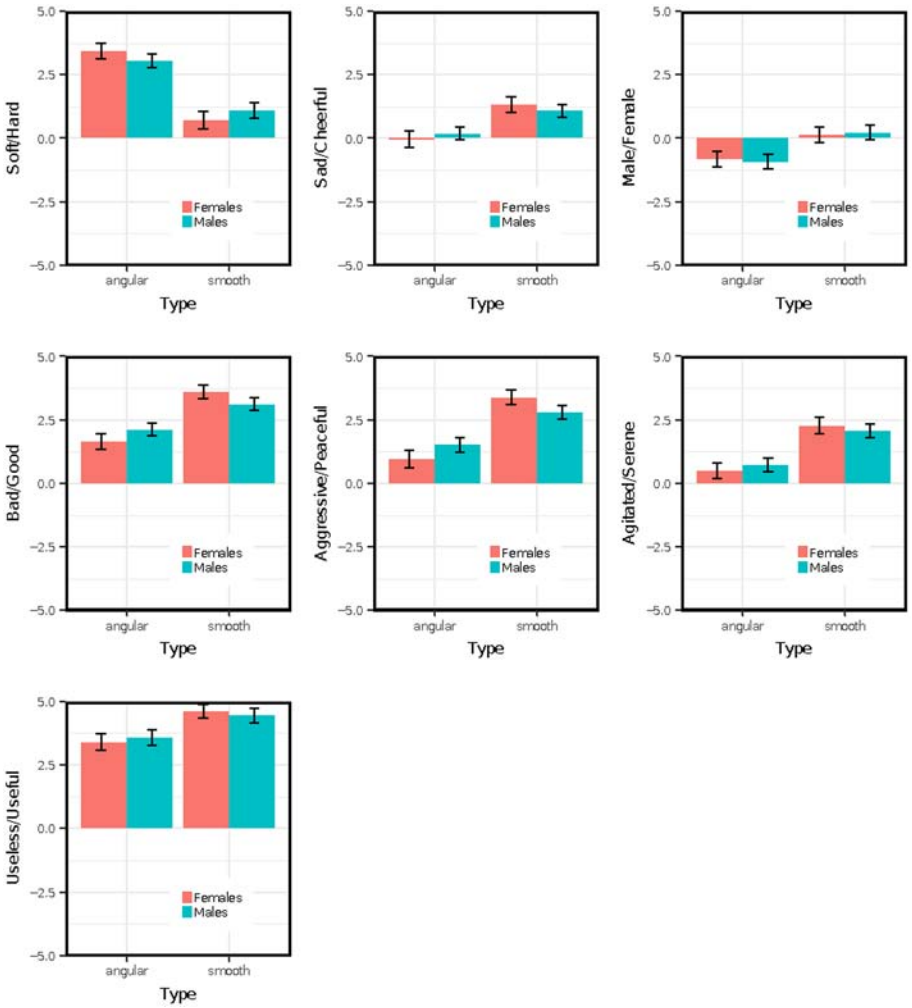

Figure 3. Mean rating for all seven categories. Error bars are ±1 standard error of the mean. Although there was no statistical difference for gender, we separate the dataset for males and females because it was balanced (42 male, 42 female) and the measures were independent. The similarity in the pattern for males and females shows the robustness of the results.

summary statistics and the graphs we use the coding listed earlier in this paragraph. Whether orientation plays a role will be tested by the factor Orientation in the analysis.

In addition to comparing the effect of type across subjects, we can also compare it across objects. We therefore report the effect of type in two one-way ANOVAs in which the second is an item analysis. Note that the degree of freedom will be different as we have 84 subjects but 175 items.

Moreover, we have estimated the relative impact of private and shared variance for each dimension (see Hönekopp, 2006). Specifically, we performed an analysis of variance using subjects and type as independent variables. In this way, the interaction subjects × type represents the private variance which we then compared with the variance of type, representing the shared variance.

3. Results

3.1. Hardness (Soft versus Hard)

The overall mean hard score was 3.22 (SD = 6.5) for angular images and 0.91 (SD = 5.7) for smooth images. There was only one significant factor in the ANOVA and that was the type: smooth images were judged as softer ($F_{1,82}$ = 73.97, $p < 0.001$, $\eta_p^2 = 0.47$). Note that the fact that angular stimuli tend to be perceived as harder is consistent with the existing literature (Walker, 2012).

The item analysis confirmed a significant effect of the variable type ($F_{1,174}$ = 80, $p < 0.001$, $\eta_p^2 = 0.31$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant interaction between the two variables ($F_{83,1932} = 1.74$, $p < 0.001$, $\eta_p^2 = 0.07$); the effect of type was also significant ($F_{1,1932} = 115.41$, $p < 0.001$, $\eta_p^2 = 0.06$). This indicates that the subjective variance for this dimension is important and similar to the objective variance.

3.2. Sadness (Sad versus Cheerful)

The overall mean score on the sad/cheerful scale was 0.07 (SD < 5.1) for angular images and 1.20 (SD = 4.8) for smooth images. There was one significant factor in the ANOVA and that was the type: smooth images were judged as more cheerful ($F_{1,82} = 21.70$, $p < 0.001$, $\eta_p^2 = 0.21$). The interaction between direction and type was also significant ($F_{1,82} = 4.33$, $p < 0.05$, $\eta_p^2 = 0.05$).

The item analysis confirmed a significant effect of the variable type ($F_{1,174}$ = 24, $p < 0.001$, $\eta_p^2 = 0.12$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 29.64$, $p < 0.001$, $\eta_p^2 = 0.01$) whilst the interaction between type and subjects was not significant ($p = 0.17$). This indicates that the subjective variance for this dimension is negligible compared to the objective variance.

3.3. Gender (Male versus Female)

The overall mean score on the male/female scale was -0.88 (SD = 6.9) for angular images and 0.17 (SD = 6.9) for smooth images. There was only one significant factor in the ANOVA and that was the type: smooth images were judged as more feminine ($F_{1,82} = 16.77$, $p < 0.001$, $\eta_p^2 = 0.17$). Note that the fact that smooth stimuli tend to be perceived as female is consistent with

the existing literature (Milan *et al.*, 2013; Palumbo *et al.*, 2015; Stroessner *et al.*, 2020).

The item analysis confirms a significant effect of the variable type ($F_{1,174} = 22.6$, $p < 0.001$, $\eta_p^2 = 0.11$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 23.63$, $p < 0.001$, $\eta_p^2 = 0.01$) whilst the interaction between type and subjects was not significant ($p = 0.16$). This indicates that the subjective variance for this dimension is negligible compared to the objective variance.

3.4. Goodness (Bad versus Good)

The overall mean bad/good score was 1.9 (SD = 5.1) for angular images and 3.4 (SD = 4.5) for smooth images. There was only one significant factor in the ANOVA and that was the type: smooth images were judged as more good ($F_{1,82} = 33.94$, $p < 0.001$, $\eta_p^2 = 0.29$). Note that the Italian words used had a moral connotation, and we are therefore talking about goodness in a less general sense than the English words have, and closer to the words 'malevolent' and 'virtuous'. In this sense the association is between angularity and malevolence.

The item analysis confirmed a significant effect of the variable type ($F_{1,174} = 42.0$, $p < 0.001$, $\eta_p^2 = 0.19$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 58.15$, $p < 0.001$, $\eta_p^2 = 0.01$). The interaction between type and subject was also significant ($F_{83,174} = 1.75$, $p < 0.001$, $\eta_p^2 = 0.05$). This indicates that the subjective judgement for this dimension is important and similar to the objective judgement.

3.5. Peacefulness (Aggressive versus Peaceful)

The overall mean peacefulness score was 1.20 (SD = 5.4) for angular images and 3.10 (SD = 4.7) for smooth images. The factor type was significant in the ANOVA: smooth images were judged as more peaceful ($F_{1,82} = 34.90$, $p < 0.001$, $\eta_p^2 = 0.30$). There was also a significant interaction between gender and type: females judged smooth images as more peaceful overall than males ($F_{1,82} = 4.26$, $p = 0.04$, $\eta_p^2 = 0.05$).

For comparison we report the main effect of type in a one-way ANOVA ($F_{1,83} = 41.0$, $p < 0.001$, $\eta_p^2 = 0.33$) and the same from the item analysis ($F_{1,174} = 54.0$, $p < 0.001$, $\eta_p^2 = 0.24$). The effect is present in both cases.

The item analysis confirmed a significant effect of the variable type ($F_{1,174} = 54.0$, $p < 0.001$, $\eta_p^2 = 0.24$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 80.42$, $p < 0.001$, $\eta_p^2 = 0.03$). The interaction between type and subject was also significant, ($F_{83,174} = 1.95$, $p < 0.001$, $\eta_p^2 = 0.07$). This indicates that the

subjective judgement for this dimension is important and similar to the objective judgement.

3.6. Serenity (Agitated versus Serene)

The overall mean serenity score was 0.61 (SD = 5.1) for angular images and 2.16 (SD = 4.9) for smooth images. The factor type was significant in the ANOVA: smooth images were judged as more serene ($F_{1,82} = 27.64$, $p < 0.001$, $\eta_p^2 = 0.25$). There was also a small but significant interaction between gender and direction ($F_{1,82} = 6.33$, $p = 0.01$, $\eta_p^2 = 0.07$). The association between angularity and the 'agitated' end of the scale is consistent with the literature (Lindauer, 1990; Milan *et al.*, 2013).

The item analysis confirmed a significant effect of the variable type ($F_{1,174} = 42$, $p < 0.001$, $\eta_p^2 = 0.19$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 56.56$, $p < 0.001$, $\eta_p^2 = 0.03$). The interaction between type and subject was also significant, ($F_{83,174} = 1.68$, $p < 0.001$, $\eta_p^2 = 0.06$). This indicates that the subjective variance for this dimension is important and similar to the objective judgement.

3.7. Usefulness (Useless versus Useful)

The overall mean useful score was 3.5 (SD = 5.8) for angular images and 4.5 (SD = 5.2) for smooth images. There was only one significant factor in the ANOVA and that was the type: smooth images were judged as more useful ($F_{1,82} = 16.61$, $p < 0.001$, $\eta_p^2 = 0.17$).

The item analysis confirmed a significant effect of the variable type ($F_{1,174} = 13$, $p < 0.001$, $\eta_p^2 = 0.07$). Furthermore, an ANOVA with type and subjects as independent variables showed a significant effect of type ($F_{1,1932} = 23.41$, $p < 0.001$, $\eta_p^2 = 0.00$). The interaction between type and subject was also significant, ($F_{83,174} = 1.03$, $p < 0.001$, $\eta_p^2 = 0.06$). This indicates that the subjective variance for this dimension is negligible compared to the objective variance.

The relationship between the different categories is shown in Fig. 4. The graph focuses on how the soft/hard dimension relates to the other dimensions across the items and shows that more hard items were also the items seen as more sad, male, bad, aggressive and agitated.

Pairwise correlations (Bonferroni-corrected) for the seven rating categories are shown in Fig. 5. We present here some of the same information plotted in Fig. 4 but in a different format. The top row shows that hardness is negatively associated with all the other dimensions. This is consistent with the negative slopes shown in Fig. 4. Note also that, in agreement with Fig. 4, when associations exist, they are very similar for the angular and the smooth items. The

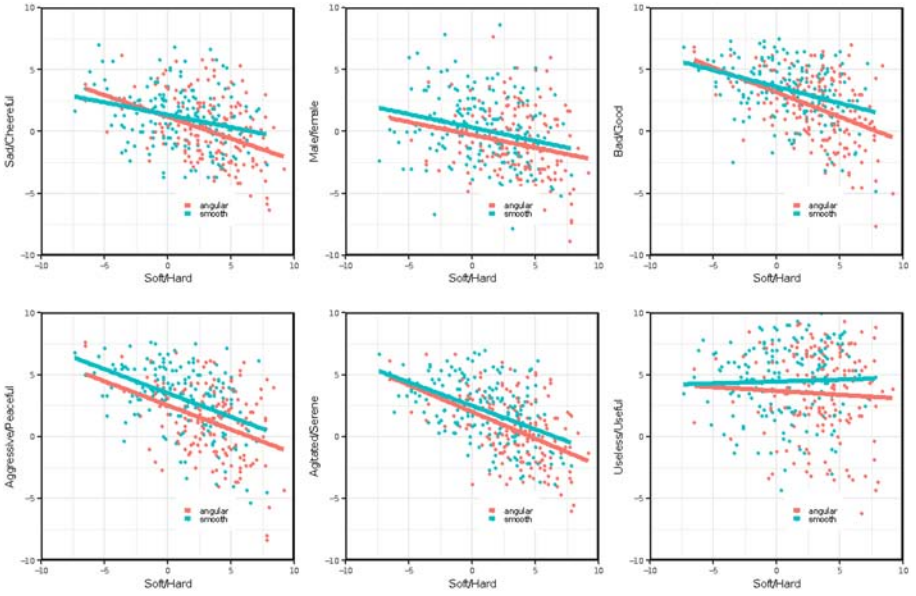

Figure 4. Scattergraphs showing the association between the responses to the soft/hard category and the responses to each of the other six categories. Each point is one item (n = 350).

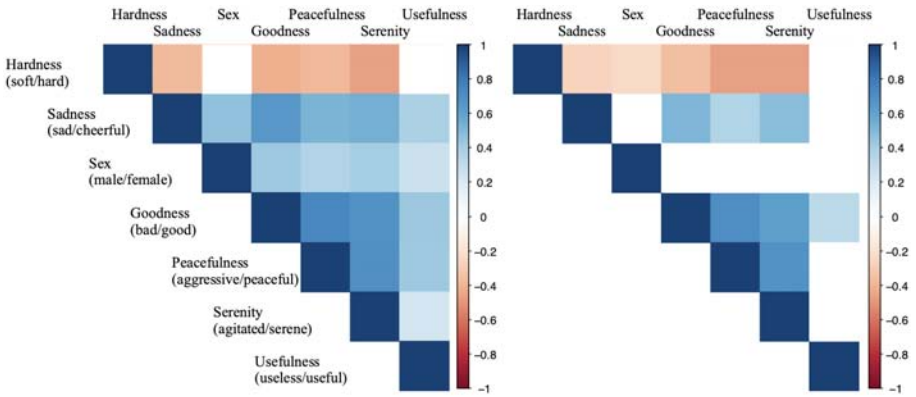

Figure 5. Correlations (Pearson's r) between the seven categories tested based on responses to the different items. The correlations are shown separately for angular (left) and smooth (right) stimuli. Blank cells indicate that the correlation was not significant.

strongest association was with the dimension aggressive/serene. Smooth shapes are seen as serene and angular shapes as aggressive. This result is in line with other studies (Lindauer, 1990; Milan *et al.*, 2013) and suggests a more analytical design way to convey perceived aggression than the anthropomorphization typically investigated in the study of product shapes, as in cars (Windhager *et al.* 2008) or in cell phones (Landwehr *et al.*, 2011).

The rest of the matrix provides additional information. For example, in the case of ratings of sadness (second row) sad scores were also perceived as good. This is consistent with a passive and harmless character of sadness, as it is discussed by Koffka (1935). In the case of gender, despite the link with the soft/hard dimension, gender was not particularly strongly linked to any of the other dimensions. It is possible to hypothesize that male and female categories could always take different emotional characters.

4. Discussion

There is a large literature that shows the human preference for smooth curvature. This preference does not depend on perceived regularity, complexity or familiarity (Bar and Neta; 2006; Bertamini *et al.*, 2016; Silvia and Barona, 2009; Tinio *et al.*, 2011). Consistently, it is common to associate the smooth curvature to friendly products or to friendly architectures (Madani Nejad, 2003; Nanda *et al.* 2013). The literature also reports some empirical evidence that smooth curvature of geometrical figures appears as peaceful (Lindauer, 1990) or calm (Milan *et al.*, 2013). However, these effects have been discussed in relation to geometrical shapes, as isolated variables, without taking into account the overall interaction of the design object. On the contrary, using drawings of objects in two versions, rounded and angular, in the current study we verified the influence of the curvilinearity/angularity factor on tertiary qualities of everyday objects drawing by junior designers.

We demonstrated the effect of the curvilinearity/angularity factor on all the categories (soft/hard, sad/cheerful, aggressive/peaceful, agitated/serene, male/female, bad/good, useless/useful). The effect concerns all the principal domains of everyday objects' expressivity and confirms that tertiary features are immanent properties of the perceptual patterns (Arnheim, 1974), in accordance also with the principle of *transparency of experience*, for which reflection on experience does not reveal that we are aware of experience itself, but of its mind-independent objects (Harman, 1990; Tye, 2000). Furthermore, other authors have recently supported the claim that these kinds of associations, between features of shapes and emotional expressions, are universal precisely because they are based on a multi-sensory code (Sievers *et al.*, 2019).

Specifically, with the new results we have found that smooth shapes are perceived as more soft, cheerful, serene, peaceful, good, and female. It is not surprising that all these characteristics are perceived together in the same object. The presence of combined multiple percepts has been studied largely in ambiguous or multistable figures, but it is also common in the expressive domain (Sinico, 2019). It is common evidence that, for instance, a table can express together hardness, solidity, and levelness, in the same way as a smile can express together cheerfulness and bitterness. These results are useful in the context of design because the user experience is generally dominated by

intersensory and emotional qualities (Norman, 2013) and the designer must be able to design with qualitative and quantitative awareness of the relevant tertiary features as a function of the global effect. The most pertinent theoretical framework for this awareness seems to be Gestalt theory. According to Gestaltists, tertiary emotional qualities of the objects are not a simple projection of the subject. Koffka, for example, argues that: "I should even be inclined to think that a field which contains no Ego organization may be highly emotional" (1935, p. 327). Secondly, Metzger (1941/1963) mainly insisted on the holistic character of tertiary qualities. This claim is supported by our experimental results. In fact, primary variables (such as curvilinearity or angularity) influence together tertiary intersensory features (such as softness or hardness) and tertiary emotional features (such as cheerfulness, serenity, peacefulness). Consistent with these views, a single perceptual variable can generate multiple perceptual effects in the tertiary domain (Sinico, 2019, 2020). These findings lead us to conclude that the designer's choice of each perceptual variable (e.g., curvilinearity or angularity) should always be designed in a holistic manner.

Although we cannot exclude that culture and common sense play a role in our results (see Carbon, 2019); we argue that these factors may add up to determinants that are objective in nature. A clue is given by the interaction between gender and type. We found that females judged curvilinear objects as more peaceful than males. It is possible that this interaction is due to gender determinants rather than biological determinants, as other studies demonstrated for the evaluation of aesthetic material (Ortlieb *et al.*, 2016), and about the preference for smooth curvature of abstract shapes (Palumbo *et al.*, 2021). In any case, further studies are necessary to clarify this issue.

The estimation of the relative impact of private and shared variance for each dimension reveals that for the sadness, gender, and usefulness dimensions the shared variance can explain these associations. This result is consistent with the assumption of a universal effect of the expressive qualities. For the remaining dimensions of hardness, goodness, peacefulness, and serenity there is an important subjective component that limits the generalization of the associations. It can be speculated that these expressive qualities are not general-oriented because of the intrinsic plurivocity of the objects rather than by personal taste. In the case of hardness, for instance, the same object can be composed of both a hard and a soft part. Conversely, usefulness is more focused on the object as a whole.

Furthermore, with regard to perceived usability, results show that smooth shapes have been perceived as more useful. As for safety (Bertamini and Sinico, 2019) so for utility, it is interesting to note that observers discriminated the object utility directly based on its shape, which makes perceived utility a structural quality, and our results suggest that utility, perceived from relational characteristics as a form of affordance (Norman, 2013), is amplified by the smooth curvature. Our results demonstrate that the designer's conception, also

on the expressive domain, is not arbitrary but is well recognized by users, with whom he shares a universal perceptual experience. This result highlights distinctive components in the preference for objects. As Arnheim wrote: "In a functional-looking object we may see the dynamics of pouring, soaring, containing, receiving, etc. (…) the gracefulness of the spout consists in the graceful pouring it displays visually" (1964, p. 35). Expressive qualities express both static values and functional ones. Curvature can express the value of behaviour in itself. The weight of these two distinctive components needs verification in future studies. The relationship between utility and the liking of products is also supported by other studies (Carbon, 2010).

These findings are also relevant in the light of the stimulation we used. The 772 drawings in the database were created by a group of junior designers. We have adopted the more general term 'drawings' in place of 'sketches' because we invited the designers to draw everyday objects without forcing the task towards a design project. However, unlike other image datasets, in these drawings by designers the curvilinearity and angularity factors are integrated into the overall aesthetic, functional, and ergonomic balance of the product. In fact, unlike naïve subjects or artists, the drawing of designers is necessarily characterized by implicit project constraints, such as the function of the artefact, usability, cost of production, pleasantness, etc. (Goldschmidt, 1991; Kavakli *et al.*, 1999; Lawson, 1980) as well as specific cognitive strategies (Tversky *et al.*, 2003; van Sommers, 1984).

It is known that project drawings also have conventional aspects and subjective dimensions (Do *et al.*, 2000). Our results allow us to explore cognitive operative mechanisms, involved in the traditional paper-based sketching (Mao *et al.*, 2020), and perceptual constraints. Perceptual constraints are the anchoring of the intersubjective experience and represent the basis for communicative exchange and the success of the project user oriented. These perceptual effects emerge from the pattern of judgements from independent observers and the stable correlations between dimensions.

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