ESTUDOS EM DESIGN
DESIGN ARTICLES

Colour in product design and its influence on User Experience (UX) and Usability (US): a cross-sectional study

Cor no design de produtos e sua influência na Experiência do Usuário (UX) e na Usabilidade (US): um estudo transversal

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Abstract
Products can generate constraints when their design does not meet the principles of usability (US) or user experience (UX). Among the design attributes that can interfere with these variables, colour stands out. The objective of the present study was to analyse the influence of colour on US and UX, during interaction with a product in different colours. The methodological procedures were characterized as inductive, empirical and exploratory. Thirty Portuguese women participated, aged between 60 and 80 years. Three identical clay sausage roasters, presented in different colours: terracotta, green and grey, were evaluated with Emotional Response Cards (ERC), a non-verbal self-report instrument; and Perceived Usability Cards (PUC), a verbal and emoji self-report instrument. The results point to an association between product colour, emotional valences and ERC cards with usability. Thus, US and UX can be applied in combination to improve the quality of products' design.

Keywords: colour, product design, user experience, usability.

Resumo
Produtos podem gerar constrangimentos quando seu design não atende os princípios de usabilidade (US) ou experiência do usuário (UX). Dentre os atributos do design que podem interferir nestas variáveis destaca-se a cor. O objetivo do presente estudo foi analisar a influência da cor na US e UX, durante a interação com um produto em diferentes cores. Os procedimentos metodológicos se caracterizaram como indutivo, empírico e exploratório. Participaram 30 mulheres portuguesas, com idade entre 60 e 80 anos. Três iguais clay sausage roaster, apresentados em cores distintas: terracotta, green and grey, foram avaliados com Emotional Response Cards (ERC), a non-verbal self-report instrument; and Perceived Usability Cards (PUC), a verbal and emoji self-report instrument. Os resultados apontam uma associação entre cor do produto, valências emocionais e cards ERC com usabilidade. Assim, US e UX podem ser aplicadas de modo associado para a melhoria da qualidade do design dos produtos.

Palavras-chave: *cor, design de produto, experiência do usuário, usabilidade.*

Introduction

Every day, thousands of people who interact with everyday products experience embarrassing situations, interfering (negatively) in their level of satisfaction and, consequently, in the user experience (UX) and/or usability (US).

UX is understood as a way of understanding user interactions with products and/or systems, which aims to explore and measure which affective, meaningful, and valuable experiences (among other qualitative factors) are achieved during interaction with a product and/or system (Vermeeren, *et al.* 2010). US can be understood as the extent to which a product (or system) can be used by specific users and in a specific context of use to achieve specific objectives with effectiveness, efficiency and satisfaction (ISO, 2018), this last dimension being characterized by being mostly qualitative. In fact, different studies focusing on these use interaction processes have been developed in recent decades (Eason, 2007; Trevisan, Steinmeier and Jakobs, 2012; Wilkinson and De Angeli, 2014; McDonagh-Philp and Lebbon, 2015; Unruh and Canciglieri Junior, 2018) and, although there is a consensus that product design should meet users' capabilities and expectations, there is still a lack of empirical research that explores and explains how the attributes inherent to the design of these products can influence the UX and US. Among the various attributes of product design, colour stands out, which is based on perception or the phenomenon of receiving a stimulus through the visual sense, and the processing of information, attributing meanings to it (Moreira da Silva, 2013). Colour perception can be influenced by physiological, cultural, age, gender, context, and other factors, which generate cognitive responses in users, influencing their emotional sensations and behaviours (Farina, 2006; Heller, 2017). Light and colour are basic stimuli of optical information, with colour being the element or information of vision that is most quickly captured (Eysenckey and Keane, 2007). Therefore, colour can interfere with the perception of product composition elements, such as volume, weight, size, temperature, texture and others, which can result in different emotional responses (Pedrosa, 2002; Csillag, 2015). According to Farina (2006, p. 127), “colour is the soul of design and is particularly rooted in human emotions”. Thus, studying the influence of product colours on UX and US, respectively, from the point of view of emotional responses and usability perception can provide important contributions to user-focused product design methods.

The present study aimed to analyse the influence of colour on emotional response (UX) and perceived usability (US), during the interaction of senior adults with everyday products with the same practical function, but with different colours. This allowed us to understand whether the two approaches (UX and US) have any association; and whether the colours of the products only influence the emotions of individuals, or whether there are other factors that contribute to improving the interaction of users with their products.

Materials and Methods

Characteristics of the study and ethical aspects

The present study was characterized as being inductive, descriptive, exploratory and cross-sectional. Since it involved Portuguese women participants, the ethical aspects met the principles set out in the “Ethics for researchers: Facilitating Research Excellence in FP72013”

(European Union, 2013), with emphasis on integrity, proportionality, confidentiality, privacy and data protection (including anonymization and coding). In addition, an informed consent form (in Portuguese) was applied.

Sampling

The sampling was characterized as being intentional convenience, not probabilistic. Thirty women participated, with an average age of 66.27 years (s.d. 4.41 years), who reported experience of using the object of study. Participants did not report vision problems or carrying out professional activities in the area of design. These criteria ensured real experience in use, strengthening the precepts of specificity of users and tasks, in addition to limiting the judgment required in the protocols (dependent variables) to the colours of the products (independent variable). The sample size met the recommendations of Serdar *et al.* (2021).

Dependent and independent variables

The independent variable was the colour applied to everyday products. The dependent variables were the level of emotional response (considered as a UX parameter); and the level of perceived usability (considered as a US parameter).

Object of the study

The object of study was a traditional Portuguese clay sausage roaster consisting of a "boat"-shaped piece (where ethyl alcohol and grape marc spirit are deposited for the flame); and transverse rods (where the sausage is deposited). It is a product produced by hand in potteries, always with a glazed finish. The definition of the clay sausage roaster as the object of study was previously planned and was directly related to the definition of the sampling. In fact, this product is strongly present and forms part of Portuguese gastronomic culture, being present in the daily lives of the adult-senior population. In this sense, this product presents a hedonic relationship with users in this segment of the population, with emphasis on participants who met the inclusion criteria for the sample. According to Haaksma, Jong and Karreman (2018), UX and US evaluations are more easily applicable to hedonic products when compared to utilitarian products, which corroborates this methodological option. The predominant colour of this product on the market is "terracotta" [NCS S 4050-Y60R], but for the present study, products were developed in two other colours: "green" [NCS S 2050-G30Y] and "grey" [NCS S 4010-R90B].

Research Instruments

The following research instruments were used:

- Informed Consent Form (ICF);
- Emotional Response Cards (ERC) - for the UX parameter - adapted from the Product Emotion Measurement Instrument - PrEmo-2 (Desmet, 2018). This is a non-verbal self-report instrument, composed of 14 cards (Figure 1-a), with representations of seven emotions of positive valences (Desire, Satisfaction, Pride, Hope, Joy, Admiration and Fascination) and seven emotions of negative valences (Disgust, Anger, Sadness, Fear, Shame, Borebom and Contempt);

- Perceived Usability Cards (PUC) - for the US parameter - adapted from the Likert scale with three anchors (Bonfim, Moreira da Silva and Paschoarelli, 2023). This is a verbal and emoji self-report instrument with three cards (Figure 1-b), each one presenting verbal information ("easy to use", "normal use" and "hard to use") in the native language (Portuguese) and a consonant emoji, following the precepts of Alismail and Zhang (2020).

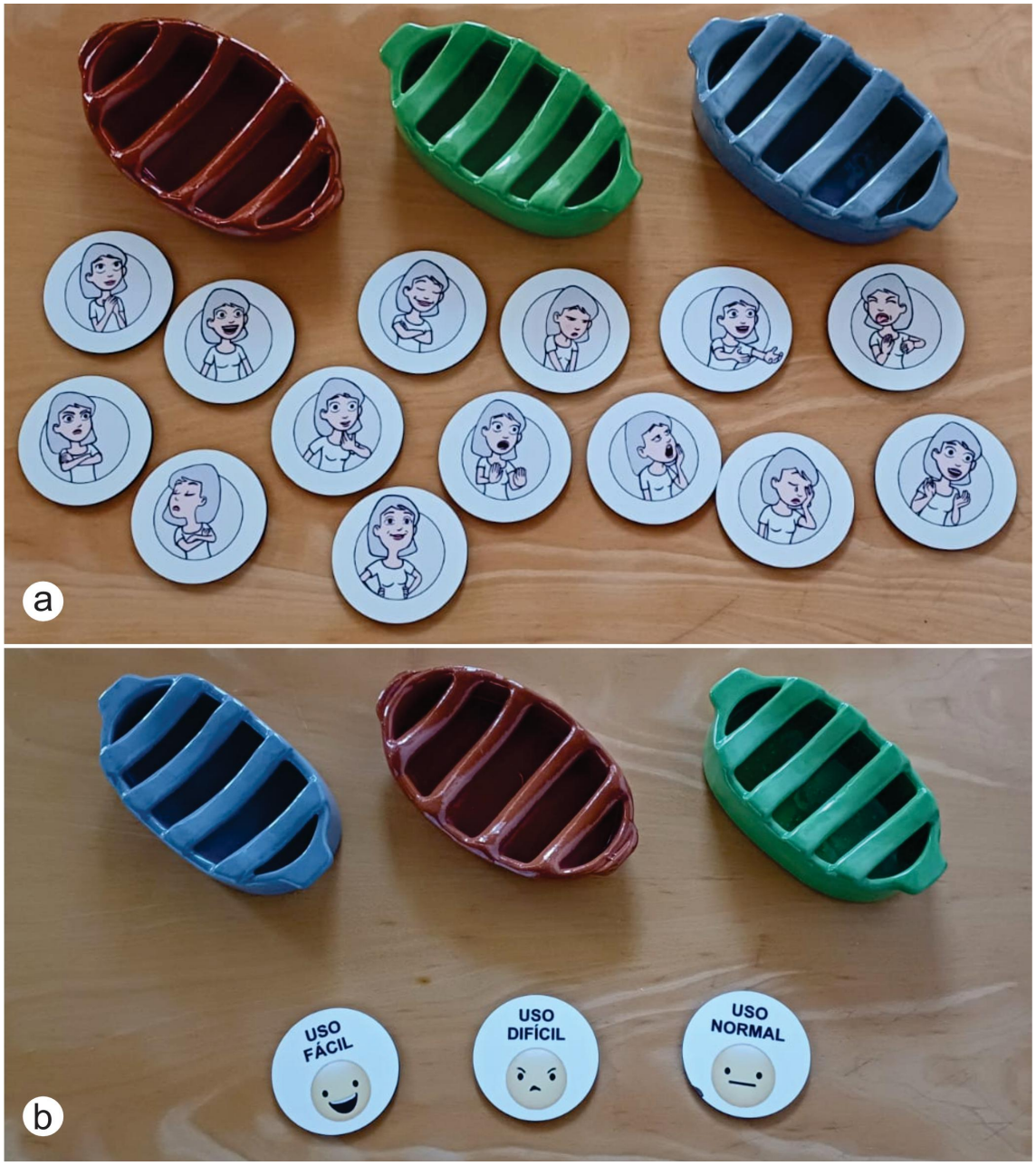

Figure 1: Clay sausage roaster, presented with ERCs (a); and with PUCs (b). Source: authors (2024).

Data Collection and Analysis Procedures

Participation was voluntary and individual, with prior application of the ICF. Both the sequence of presentation of the products, as well as the ERCs and PUCs, occurred in a randomized manner (Figure 1).

The products were presented on a table and it was reported that, despite their similarities in shape, they differed mainly in colour. This perception was confirmed by each of the participants who confirmed that they had already used the primary function (sausage roaster) of this type of product. Next, the ERCs were randomly made available (Figure 1-a). Oral instructions explained how, arbitrarily, the ERCs should be associated with the colours of the products simply by transferring the chosen card to the corresponding product. At least one card had to be associated with each of the three products, and there were no limits on the number of cards per product. After the participants stated that they had completed the association between cards and the colours of the products, a photographic image was taken to ensure the record for later tabulation of data. All cards were then removed from the evaluation area. In a second step, the PUCs were presented, also randomly available (Figure 3-b) and with similar instructions, but with the express need to associate each card with a single colour. At the end of the association, a photographic image guaranteed the record for later tabulation of data, concluding the data collection stage. In general, all participants demonstrated interest and understanding of the instruments and procedures, including reporting explanations about the associations made. With the recording and tabulation of the results, descriptive statistical analysis was applied, obtaining the frequency and relative percentage of the dependent variables. Initially, the degree of association between the ERCs was analysed using the Cramer's V coefficient, whose results close to zero suggest no associations between ERCs; and $V > 0.25$ indicate a strong degree of association (Akoglu, 2018). According to Sapra and Saluja (2021), Cramer's V is an appropriate association test for situations where the number of data requires a contingency table with a structure greater than 2 x 2. To verify the relationship between product colours (independent variable) and perceived usability (dependent variable), the ordinal logistic regression procedure was used. According to Silva, Silva and Gontijo (2017) the Odds Ratio (OR) is an estimator that expresses the chance of participants reporting an alternative higher on the ordinal response scale of the dependent variable. In order to relate (search for association between) the ERC results and usability, two other ordinal logistic regression models were constructed. The first related the results of the positive and negative valence cards (independent variables) obtained by the ERC to the usability index (dependent variable). The second related the results of each ERC card (independent variable) to the usability index (dependent variable). In this case, cards that presented a <0.10 p-value in the univariate model were selected for the multivariate model. OR values were also extracted from these models to express the chance of participants reporting a higher alternative on the ordinal response scale of the dependent variable.

Results

The results of the Emotional Response (based on the ERC), in frequency and relative percentage, are presented in Table 1. The degree of association between the ERCs showed a value of $V > 0.25$ (Cramer's V coefficient) only between the Shame and Contempt cards. The other associations presented V close to zero, demonstrating some independence in the choice of ERCs and indicating that the choice of one card does not necessarily imply the choice of another card together, reinforcing that the instrument was suitable for the present study. The Perceived Usability results (based on the PUC), in frequency and relative percentage, are shown in Table 2.

EMOTIONAL RESPONSE (ERC)							
POSITIVE VALENCE				NEGATIVE VALENCE			
Emotion	Colour	Frequency	% (Relative)	Emotion	Colour	Frequency	% (Relative)
Desire	Terracotta	10	66.67	Disgust	Terracotta	0	00.00
	Green	5	33.33		Green	0	00.00
	Grey	0	00.00		Grey	4	100.00
Satisfaction	Terracotta	6	42.86	Anger	Terracotta	0	00.00
	Green	4	28.57		Green	0	00.00
	Grey	4	28.57		Grey	6	100.00
Pride	Terracotta	3	33.34	Sadness	Terracotta	1	20.00
	Green	6	66.66		Green	2	40.00
	Grey	0	00.00		Grey	2	40.00
Hope	Terracotta	7	77.78	Fear	Terracotta	0	00.00
	Green	1	11.11		Green	2	50.00
	Grey	1	11.11		Grey	2	50.00
Joy	Terracotta	14	66.66	Shame	Terracotta	0	00.00
	Green	5	23.81		Green	0	00.00
	Grey	2	09.53		Grey	11	100.00
Admiration	Terracotta	4	25.00	Borebom	Terracotta	0	00.00
	Green	9	56.25		Green	1	50.00
	Grey	3	18.75		Grey	1	50.00
Fascination	Terracotta	5	41.66	Contempt	Terracotta	0	00.00
	Green	6	50.00		Green	1	10.00
	Grey	1	08.34		Grey	9	90.00

Table 1. Emotion Response results (based on the ERC), described in frequency and relative percentage. Source: authors (2024).

PERCEIVED USABILITY (PUC)			
Perception	Colour	Frequency	R. Percent (%)
EASY TO USE	Terracotta	22	73.33
	Green	8	26.67
	Grey	0	00.00
NORMAL USE	Terracotta	8	26.67
	Green	16	53.32
	Grey	6	20.00
HARD TO USE	Terracotta	0	00.00
	Green	6	20.00
	Grey	24	80.00

Table 2. Perceived Usability results (based on the PUC), described in frequency and relative percentage. Source: authors (2024).

The results of the regression model (Table 3) indicate that, in relation to the colour "terracotta" (reference colour), the colours "green" and "grey" have, respectively, 88.99% (OR = 0.1101; p-value = 0.0001) and 99.45% (OR = 0.0055; p-value = 0.0001) less chance of obtaining a higher usability score. Thus, there is strong evidence that the colour "terracotta" provides greater perceived usability. To ensure this statement, the reference colour was changed to green, finding a 95.03% reduction in the chance (OR = 0.0497; p-value = 0.0001) for the colour grey; and a 9-fold increase in the chance (OR = 9.0811; p-value < 0.0001) for the colour terracotta. When inserting gray as the reference colour, an increase in the chance of the usability score was observed by 20 times (OR = 20.11; p-value = 0.0001) and by more than 100 times (OR = 182.67; p-value = 0.0001) for the colours green and terracotta, respectively. These findings suggest that the product in the colour "terracotta" has a higher degree of usability as opposed to the product in the colours "grey" and "green".

Colour	*Coef*	*S.E.*	*Wald Z*	*p-value*	*OR (95% CI)*	Decision
Terracotta	Reference Colour					
Green	-2.21	0.58	-3.80	0.0001	0.1101 (0.3440 - 0.0353)	Reduces the chance
Grey	-5.21	0.77	-6.78	0.0001	0.0055 (0.0247 - 0.0012)	Reduces the chance
Green	Reference Colour					
Grey	-3.00	0.65	-4.65	0.0001	0.0497 (0.0140 - 0.1764)	Reduces the chance
Terracotta	5.21	0.77	-6.78	0.0001	9.08 (2.91 - 28.37)	Increases the chance
Grey	Reference Colour					
Terracotta	5.21	0.77	-6.78	0.0001	182.67 (40.55 - 822.90)	Increases the chance
Green	3.00	0.65	4.65	0.0001	20.12 (5.67 - 71.36)	Increases the chance

Table 3. Regression model for the relationship between colours and usability. (Captions: OR - odds ratio; CI - Confidence Interval). Source: authors (2024).

Table 4 presents the relationship between ERCs of positive/negative valences and perceived usability. It was evident that, for each positive valence card, there is a 2-fold increase (OR = 2.42; p-value = 0.010) in the chance of increasing perceived usability. On the other hand, each negative valence card reduces the chance of perceived usability by 70.43% (OR = 0.2957; p-value = 0.0151). Therefore, the ERC presents properties that relate to perceived usability.

Valence	*Coef*	*S.E.*	*Wald Z*	*p-value*	*OR (95% CI)*	Decision
Positive	0.89	0.34	2.58	0.0100	2.43 (1.24 - 4.76)	Increases the chance
Negative	-1.22	0.50	-2.43	0.0151	0.2957 (0.1107 - 0.7900)	Reduces the chance

Table 4. Regression model for the relationship between ERCs valences and usability. (Captions: OR - odds ratio; CI - Confidence Interval). Source: authors (2024).

Table 5 presents the univariate and multivariate regression model with results that relate each of the ERCs and the usability level.

ERC		Univariate Model					Multivariate Model					
		Coef	*S.E.*	*Wald Z*	*p-value*	*OR (95% CI)*	*Coef*	*S.E.*	*Wald Z*	*p-value*	*OR (95% CI)*	**Decision**
Positive Valence	**Desire**	1,91	0,58	3,27	0,0011	6,75 (2,15 - 21,24)	2,10	0,66	3,18	0,0015	8,17 (2,24 - 29,82)	Increases the chance
	Satisfaction	-0,36	0,52	-0,69	0,4893	0,70 (0,25 - 1,94)	-	-	-	-	-	-
	Pride	0,78	0,64	1,23	0,2182	2,19 (0,63 - 7,59)	-	-	-	-	-	-
	Hope	1,13	0,67	1,68	0,0938	3,09 (0,83 - 11,55)	1,67	0,76	2,20	0,0278	5,32 (1,20 - 23,55)	Increases the chance
	Joy	1,46	0,49	2,98	0,0029	4,29 (1,65 - 11,18)	1,48	0,54	2,73	0,0064	4,38 (1,51 - 12,66)	Increases the chance
	Admiration	1,16	0,51	2,25	0,0242	3,18 (1,16 - 8,68)	1,66	0,60	2,76	0,0058	5,27 (1,62 - 17,13)	Increases the chance
	Fascination	0,79	0,55	1,43	0,1523	2,21 (0,75 - 6,52)	-	-	-	-	-	-
Negative Valence	**Disgust**	-8,29	20,82	-0,40	0,6904	0,00 (0,00 - 1,3E+20)	-	-	-	-	-	-
	Anger	-2,53	1,11	-2,27	0,0229	0,08 (0,01 - 0,70)	-	-	-	-	-	-
	Sadness	-1,98	1,16	-1,72	0,0859	0,14 (0,01 - 1,32)	-	-	-	-	-	-
	Fear	-1,60	1,20	-1,33	0,1833	0,20 (0,02 - 2,13)	-	-	-	-	-	-
	Shame	-2,60	0,81	-3,19	0,0014	0,07 (0,02 - 0,37)	-1,76	0,86	-2,05	0,0400	0,17 (0,03 - 0,92)	Reduces the chance
	Borebom	1,03	1,29	0,80	0,4227	2,81 (0,22 - 35,11)	-	-	-	-	-	-
	Contempt	-2,44	0,82	-2,98	0,0029	0,09 (0,02 - 0,43)	-	-	-	-	-	-

Table 5. Univariate and Multivariate Regression Model for the relationship between ERCs and usability. (Captions: OR - odds ratio; CI - Confidence Interval). Source: authors (2024).

The ERCs of positive valence Joy (OR = 12.66; p-value = 0.0064) and Fascination (OR = 17.13; p-value = 0.0058) increased the chance of better usability by more than 10 times; Desire (OR = 29.82; p-value = 0.0015) and Hope (OR = 23.55; p-value = 0.0278) increased this same chance by more than 20 times. Regarding ERCs with negative valence, in the multivariate model only the emotion Sadness reduced the chance of better usability by 82.76% (OR = 0.1724; p-value = 0.0400). However, cards of the emotion Anger (OR = 0.0797; p-value = 0.0229) and emotion Contempt (OR = 0.0870; p-value = 0.0229) reduced the chance of better usability by more than 90%. In general, a relationship between ERCs and the degree of usability was evident.

Discussion

The design of a product can be considered one of the most important aspects that influence user interaction, impacting (positively or negatively) the UX and/or US parameters. Its physical

structure, composed of numerous attributes, among which colour stands out, is what helps to materialize the user interface. Several studies have already explored the colour attribute and the interaction of using a product (Sonderegger and Sauer, 2010; Na and Suk, 2014; Ding *et al.* 2021; Alves *et al.*, 2022; and Bonfim, Moreira da Silva and Paschoarelli, 2023), however, there are still gaps around this topic. The present study, of an empirical and cross-sectional nature, aimed to analyse the influence of colour on the emotional reaction (UX parameter) and on the perceived usability (US parameter), during the interaction with a product of everyday use, making it possible to understand how the UX and US responses may (or may not) be associated in this type of approach. The findings of the present study point to a strong and robust association between the UX and US observed in the results of the ERC used to analyse the UX parameter; and of the PUC used to analyse the US parameter.

First, we sought to understand the degree of association between the ERCs, applying an analysis based on the Cramer's V coefficient. The results showed that, with the exception of the Shame and Contempt cards ($V > 0.25$), all other associations showed that the instrument determines independence in the choice of cards. In this sense, we can state that the results of the ERCs present a significant rate of recognition of emotions (expressed spontaneously by several participants), a quality already highlighted by Desmet and Schifferstein (2012); Laurans and Desmet (2012); and Desmet (2018). The findings of the regression model (Table 3), relating the product colours to the perceived usability results help to confirm that products in the colours gray and green considerably reduce the chances of obtaining a higher level of usability when compared to the product in the colour terracotta, confirming that colour influences not only the esthetic perception of individuals, but also the usability of the product. This is corroborated by the findings of Bonfim, Moreira da Silva and Paschoarelli (2023), who studied colours on mineral water packaging and found that colours different from the traditional ones lead to a greater perception of difficulty in use, which represents a lower usability of the product.

The results of the regression model, relating valences (positive and negative) of the ERCs and usability (Table 4), indicate that the cards with positive valences are associated with an increase in US; while the cards with negative valences are associated with a decrease in US. In this sense, it is observed that the ERC presents a significant association with usability.

To understand how expressive this association is, two other models of ordinal logistics regression was applied: univariate and multivariate. In this case, the results (Table 5) indicate that the emotions Joy, Fascination, Desire and Hop have often increased the chances of the US; while the emotions Anger and Contempt, in reverse, have decreased the chances of the US several times. The option of a robust statistical support for the analysis of these data is justified by the need to present reliable results and can complement the results of other strictly qualitative studies.

In short, the highest contribution of these results is the indication that the ERC instrument, despite being recommended as an emotional evaluation and UX (Desmet and Schifferstein, 2012; Lauran and Desmet, 2012), presented a strong association with the results of the US. This helps to better understand how the UI and UX can or may not be associated. In fact, the controversies between US and UX attributions have already been explored by Bevan (2009), Beccari and Oliveira (2011) and Bitkina, Kim and Park (2020), and US is usually applied to the

development steps of product design (or system), while UX addresses “measurable qualities of use, which can be applied when artifact is being used in a real context” (KUROSU, 2019, p. 158). Albert and Tullis (2023) point out that the Usability Professions Association came to be called the User Experience Professionals Association in 2012; representing that the UX can be considered an evolution of the US. Therefore, the authors advocate that studies in these areas have encompassed a wide range of experiences, factors and variables which requires meeting some important recommendations: UX methods need to be constantly perfected; they need to meet different domains of experience; need to integrate instruments and protocols. In this regard, Vermeeren *et al.* (2010) recommend the need for application and integration of methods supported by solid procedures, aiming to achieve more reliable results to product design.

Conclusions

Product design has different attributes that aim to ensure adequate interaction of use (ie: the colour). The present study aimed to analyse the influence of the colour attribute on emotional response (UX) and perceived usability (US), during the interaction of senior adult individuals with everyday products of the same practical function, but with different colours.

The main findings indicate an association between UX and US in this type of interaction of use, pointing out that colour not only contributed to a better emotional response, but also to a satisfactory perception of product usability. In addition, robust statistical analysis indicated that in the instrument to evaluate the UX parameter (ERC), both emotional valences and the cards themselves, presented high association with perceived usability. In summary, US and UX can be considered associated in the evaluation of the quality of interaction between users and everyday use products, which complements the analysis methods and the continuous improvement of product design.

Among the observed limitations is the functional limitation and chromatic variability of the object of study. In this sense, it is recommended in future studies to use products with functional variation (ie: technological information and communication products) and, consequently, the involvement of different groups of users (as for age groups, niches of consumption, among others). It is also recommended to use other US or UX evaluation metrics with the participation of employees from other areas that orbit the subject, such as psychologists, sociologists, marketing professionals, among others. Our main conclusion is that product design should strongly consider the associated use of US or UX during product development methods, aiming to ensure the quality of design and, consequently, the quality of interaction between users and products.

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