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The Tactile Dimensions of Abstract Paintings: A Cross-Modal Study

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Abstract

In our research, we tested for the existence of cross-modal visual and tactile associations in the experience of abstract art. Specifically, we measured the association of 60 abstract paintings with four couples of antonyms related to texture, such as warm or cold, smooth or rough, lightweight or heavy, soft or hard, investigating if the different modality of presentation on a computer screen (color versions: natural colors, inverted colors, black and white) gave rise to different associations relative to the four couples of opponent qualities. Second, we tested whether there might be differences between the ratings of the paintings when they were presented as images on a computer screen versus in real life at the museum. The results confirmed that associations between visual and tactile experience with such complex stimuli exist. In the case of the couple warm or cold, a significant inversion of associated qualities occurs when the images are presented in inverted colors as opposed to natural colors; furthermore, when presented in black and white, warm evaluations are "cooled down," but cold evaluations remain the same. The degree of smoothness could be considered not associated with the color versions. When seen in black and white, both the mean softness and the mean lightweight-ness of the paintings were reduced; however, in the last case, this effect was more evident for the most lightweight pictures. There is only a slight difference between the two presentations of the paintings as images presented

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on a computer screen and seen in real life, relative to the warm or cold and soft or hard dimensions. Of the four opponent qualities, the three pairs warm or cold, lightweight or heavy, and soft or hard showed the most interesting results in relation to the cross-modal associations.

Keywords
Abstract painting, cross-modal association, texture, touch, top-down influence, vision

Introduction

In his pioneering work on touch, antecedent to his more famous work on color (Katz, 1930), Katz (1925) distinguished different modes of touch analogous to the different modes of color appearance (i.e., surface-touch, film-touch, and volume-touch; see also MacLeod, 1954). Katz also stressed the importance of a phenomenological approach to the study of touch consisting in observing and describing the characteristics of human experience without bias. Today the domain of haptics studies ranges among perception of surfaces, objects in space, bulky touch, and touching through a transparent film (see Yoshida, 1968). The main fields of research are object perception and action, and multisensory integration. Specifically, multisensory integration occurring among the different modalities is a basic field of inquiry in neurophysiology and neuropsychology (Spence & Driver, 2004) which consists of quantitative analysis of how features bind in the different modalities and which specific features or metrics they are based on. In the field of multisensory integrations, haptics has been studied predominantly in relation to vision (Cinel, Humphreys, & Poli, 2002; Kadunce, Vaughan, Wallace, & Stein, 2002), although other interactions have been analyzed, such as that between haptics and acoustics (Hall, Pastore, Acker, & Huang, 2000; Occelli, Spence, & Zampini, 2010, 2013). There is a large body of evidence that haptics interacts with vision and visual space, especially when the stimuli are close to each other (Pavani, Spence, & Driver, 2000), and it has also been shown that an increased activity is detected in the inferior parietal lobes when tactile-visual matching tasks are performed (Banati, Goerres, Tjoa, Aggleton, & Grasby, 2000).

The relationship between vision and haptics is also evidenced by the parallels often drawn between tactile and visual illusions on the basis of the finding that some tactile illusions appear to have counterparts in vision, as in the case of the cutaneous touch rabbit illusion (Geldard, 1976; Geldard & Sherrick, 1972; Hayward, 2008). This relationship has been studied with respect to the laws of perceptual organization, where a difference between the two modalities has been found: In the case of vision, for example, the law of good continuation (through which one perceives parts with a different orientation as one unified object, such as the case of intersecting lines in an "x" shape) dominates. In contrast in tactile perception, the laws of common center (through which one may identify by touch a star shape, which appears visually as two intersecting triangles) and the law of closure (through which the amodal perception of complete shapes is viewed as if partially occluded—this effect is sometimes stronger than the Gestalt laws of proximity and similarity) prevail (Metzger, 1936, Ch. 4). Common patterns between visual and tactile perception have however been found in the analysis of shape and texture dimensions of haptics (Okamoto, Nagano, & Yamada, 2013; Yoshida, 1968). In particular, classic dimensions of texture are considered to be warmness or coldness, smoothness or roughness, softness or hardness, and dryness or wetness (Bergmann & Kappers, 2014; Hollins & Bensmaia, 2007; Hollins, Faldowski, Rao, Young, 1993; Jones, & Lederman, 2006; Nagano, Okamoto, & Yamada, 2012). In general, studies in the field of tactile perception of texture make use of rather simplified stimuli, for example artificially produced surfaces such as gratings, sandpaper, etched surfaces, and so forth (Gescheider, Bolanowski, Greenfield, & Brunette, 2005; Ho, Iwai, Yoshikawa, Watanabe, & Nishida, 2014; Klatsky, Lederman, & Reed, 1989; Lederman & Abbott, 1981). Other studies have analyzed textile fabrics (Picard, Dacremont, Valentin, & Giboreau, 2003), and sometimes more natural stimuli such as straw and wood have been used. It has recently been shown that the psychophysics of many tactile qualities exhibit complex, multidimensional, higher order relations (Bergmann Tiest, Kosters, Kappers, & Daanen, 2012).

In recent years, the relationship between vision and tactile perception has been studied from the viewpoint of synesthesia and cross-modality. In particular, there is a growing body of research in the field of cross-modal associations. These studies show that the general population (and not synesthetes alone) experiences cross-modal associations in the different modalities (Cohen Kadosh, Henik, & Walsh, 2009; Deroy, Crisinel, & Spence, 2013; Deroy & Spence, 2013; Marks, 1978; Martino & Marks, 2001; Maurer & Mondloch, 2005; Parise & Spence, 2009; Sagiv & Ward, 2006; Simner, Gartner, & Taylor, 2011; Simner, Lanz et al., 2005; Spector & Maurer, 2008, 2011; Ward, Huckstep, & Tsakanikos, 2006; Ward, Li, Salih, & Sagiv, 2007; for a review, see Spence, 2011). The same occurs within different dimensions of the same modality, vision for example (Albertazzi, Canal, Dadam, & Micciolo, 2014; Albertazzi, Canal, Malfatti, & Micciolo, 2015; Albertazzi, Da Pos et al., 2013; Dadam, Albertazzi, Da Pos, Canal, & Micciolo, 2012; Spector & Maurer, 2008, 2011). The results on cross-modality obtained to date are in favor of the neonatal synesthesia hypothesis of Maurer (1993), according to which humans are born with cross-modal connectivity which slowly decreases over the years due to several factors, for example, neural pruning (Maurer & Maurer, 1988) and inhibitory processes (Spector & Maurer, 2009). In fact, a similarity has been found between the experiences of synesthetes and nonsynesthetes (Ward et al., 2006). Among the various cross-modal associations in synesthetes (vision and sound, vision and taste, sound and taste, sound and smells, etc.), the association between visual and tactile stimuli has been the least studied (Day, 2005; Ludwig & Simner, 2013; Simner & Ludwig, 2012; Slobodenyuk, Jraissati, Kanso, Ghanem, & Elhajj, 2015; Steven & Blackemore, 2004; Whitaker, Simoes-Franklin, & Newell, 2008), despite the fact that the touch-color association has been shown also in the general population (Martino & Marks, 2000; Ward, Thompson-Lake, Ely, & Kaminski, 2008). The need to develop a reference frame in which to test cross-modality effects of vision and touch has been demonstrated by testing three dimensions that varied the physical parameters of temperature, roughness, and hardness on five levels each (Jakesch, Zachhuber, Leder, Spingler, & Carbon, 2011).

In our research, we tested whether systematic cross-modal visual and tactile associations occur among the general population also with stimuli of higher order complexity and using a phenomenological method based on subjective judgments (Katz, 1925). We tested the existence of a cross-modal association between the visual appearance of a group of abstracts paintings and certain tactile characteristics evaluated according to four pairs of antonyms using the Osgood semantic differential (Okamoto et al., 2013; Osgood, 1956). Specifically, we tested whether abstract paintings with varying perceptual characteristics led to consistent associations with attributes related to tactile perception, and which of them might be responsible for the phenomenon. The hypothesis was that material properties of paintings, more formally evident in the case of abstract art, as experienced in vision, have a clear and vivid phenomenology cross-modally associated with tactile experience. The rationale for choosing abstract paintings as stimuli is due to the extreme complexity and abstraction of the paintings themselves, which replicate the complexity of a real-everyday scene, while focusing the observer on the quality of the image, which has no contextual narrative. Other complex stimuli, such as everyday scenes wouldn't fit the scope of our research, because immediately bearing tactile perception associated to known visual elements. In short, we wanted to test the association exclusively with formal and decontextualized features.

The Study

In our research we tested whether, in general, there exists a cross-modal association between vision and haptics in the visual experience of abstract paintings. There were several reasons for choosing such complex stimuli. Generally, the stimuli used in cross-modal analyses are rather simple (colors, sounds, single olfactory perceptions, graphemes, etc.). However, in a previous study that we had conducted on cross-modal association between vision and acoustics, where we tested paintings and clips of classical music, the results showed that the association exists also in cases of complex stimuli such as those that we commonly experience in the environment (Albertazzi, Canal, & Micciolo, 2015a). In the research reported here, we wanted to test whether the association exists with stimuli of high complexity in the modalities of vision and haptics. Differently from the previous test, the paintings were not by the same painter, but they pertained to a well-defined style, place, and period of art (Italian abstract painting between 1934 and the 1970s). The selection of the paintings was motivated by the presence—during the experiment—of an exhibition of Italian abstract painter Mario Radice and his professional artist peers at the Museum of Modern and Contemporary Art of Rovereto and Trento (MART, *Mario Radice. Architecture Number Color,* Rovereto, February 14, 2014–June 8, 2014: http://www.mart.trento.it/marioradice), which afforded the opportunity of testing subjects on a sufficiently varied and suitable set of real artworks. Interestingly, many artists who create abstract art, including some involved in the exhibition, have expressed interest in multisensoriality and the link between touch and vision (Bacci, 2011, 2014; Bacci & Melcher, 2013; Bacci & Pavani, 2014). In fact, because this is not representational art (such as landscapes, portraits, still lives, etc.), which depicts objects known and widely present in the environment, the cross-modal perception of tactile characteristics of abstract objects seem particularly significant for analysis.

The dimensions tested were therefore certain material properties of texture such as warmness or coldness, smoothness or roughness, lightness or heaviness, and softness or hardness. We did not test the dimension of dryness or wetness, usually correlated with fluidity, but decided instead to test the lightness or heaviness dimension, which we believed to be more closely correlated with the visual appearance of the stimuli. Nor did we test shapes (i.e., dimensions such as large or small, thin or thick, bi- or three dimensionality, etc.), because it has been shown that material properties are more basic in the exploration of unfamiliar objects. Nor, moreover, did we test the affective dimensions (i.e., whether the paintings appeared clean or dirty, rich or poor, pleasant or unpleasant, etc.), restricting our inquiry to perceptual dimensions only as phenomenologically perceived by the subjects, instead than qualities that were going to be the result of a judgement.

The goal of the experiment was to verify whether the textures and colors of the paintings were associated with tactile perception also with highly complex stimuli and what dimensions may have been responsible for the association. The test was conducted in two phases. In the first phase, the association was verified with four couples of contraries. Use was made of the Osgood semantic differential (OD; Osgood, 1956), which was applied to the study of tactile impressions by Yoshida (1968). We did not employ a method based on speeded classification tasks (Marks, 2004), because for our purposes OD was the most appropriate methodology in that it provides a scale with which to measure the perceptual ratings of the material properties of the stimuli, such as hard or soft, using adjective labels. According to Yoshida (1968), in fact, OD yields more clear-cut results than multidimensional scaling also in the case of stimuli consisting of touchable samples.

If shown to be consistent, the regularity of the associations between certain visual texture characteristics of abstract paintings and specific attributes related to tactile perception would support the hypothesis of a correspondence between the two modalities at the phenomenological level. We chose to test certain classic dimensions of texture materials such as warmness or coldness, smoothness or roughness, lightness or heaviness, and softness or hardness to evaluate if three different modalities of presentation on a computer screen (i.e., with natural colors, with inverted colors, and in black and white) gave rise to different associations relatively to the four couples of contraries. In the second phase, we tested whether there were differences in the subjects' determination of textural qualities when viewing of the paintings as images on a computer screen versus the paintings seen from real at the museum.

Methods

Participants

Twenty-five adult participants volunteered for two experiments: 16 women and 9 men (mean age: 37.2 years; standard deviation: 8.5; median: 37 years).

All participants were recruited through an online advert posted on a subject-recruiting website used by Trento University researchers and the Education Department of the MART. In the experiments, the only exclusion criterion was self-reported defective color vision or conscious synesthesia. All the subjects signed an informed consent form and answered a questionnaire regarding their visual acuity, gender, familiarity with arts, and nationality. The subjects were all Italian except four (one American, one Chilean, one Argentine, and one Italian–Canadian), who were included since they displayed an almost complete fluency in the use Italian language; six subjects were not familiar with art; five could not participate in the second experiment at the Museum because of overlaps between the opening and closing hours of the Museum and their work schedules. The 20 participants who completed the second phase of the experiment at the MART were all Italians with the exception of the four mentioned earlier.

The experiments reported here complied with the current Italian and European Community laws in terms of ethical treatment and according to the Trento University Ethical Committee.

First Phase of the Experiment

General Materials

The first phase of the experiment was performed in a laboratory with constant and controlled lighting conditions (230–250 lux) in the room (correlated color temperature 3400 K, halogen lamp). The visual stimuli appeared on a Quato Display 242ex (Intelli Prof 242 excellence) a 24″ screen (51.8×32.4 cm visible area). Automatic 48-bit USB-hardware calibration with 3×16-bit 3D look-up table and luminance inside the monitor, dedicated luminance stability circuit, UDACT display analysis built-in; the measurement device was a 4-channel Silver Haze Pro colorimeter. The resolution used was 1920×1200 pixels (the native and the maximum possible for the Display Quato 242 monitor). The temperature of the room was about 20°.

The materials consisted of a series of 60 paintings (by different painters) and a list of eight adjectives. We used 60 nonfigurative paintings by the Italian abstract painter Mario Radice and some of his professional artist peers (titles and authors of the paintings are given in the supplementary materials). In the experimental task, subject had to rate the presence in each painting of tactile qualities commonly attributed to the texture of objects in the environment, on the basis of their visual judgment. Two of the authors were subjected to a preliminary analysis of the adjectives in relation to the paintings, which they grouped into categories in virtue of their semantic proximity, so that each one of the adjectives resulted to be synonyms of one of the eight adjectives used in the test phase. The list of the four pairs of adjectives (presented in Italian) was warm or cold (caldo or freddo), smooth or rough (liscio or ruvido), lightweight or heavy (leggero or pesante), soft or hard (morbido or duro).

For the assessment, the adjectives were presented in pairs of opposites, that is, soft versus hard, with a 7-point scale separating them (1 = *very hard*; 2 = *quite hard*; 3 = slightly hard; 4 = *neither hard nor soft OR both hard and soft in equal proportions*; 5 = *slightly soft*; 6 = *quite soft*; 7 = *very soft*). A rating of 4 was neutral (i.e., indicating that the painting was judged as possessing either both qualities in equal proportions or neither of the two qualities); a rating of 1 or 7 indicated the presence of one quality or the other exclusively; any other number indicated a degree of one quality accompanied by a degree of the other.

Procedure

The subjects were required to take part in two experimental sessions, which needed to be at least 3 days apart. The first part of the experiment was conducted in the Experimental Psychology Lab at the Center for Mind/Brain Sciences at the University of Trento. It entailed viewing 60 abstract paintings on a computer screen, 20 of them with natural colors, 20 of them with inverted colors, and 20 presented in black and white. Each subject saw a randomized series of all 60 paintings in the selection and never saw the same painting in different color versions. Each participant saw 20 paintings in the natural colors, 20 in inverted colors, and 20 in black and white. Each painting was shown only once, in one of the three color versions just described (Figures 1 and 2).

The experiment was performed using the OD (Osgood, 1956) on a bipolar rating scale of adjectives. The choice of the method was due to its value in visually assessed tactile perception of texture and because, in our case, the stimuli could not be touched physically.

The participants were told that they were going to be shown a set of 60 images of abstract paintings on a neutral gray background, one at a time on the computer screen positioned in front of them to the left. The task was to evaluate each picture according to the four pairs of adjectives shown on another computer screen positioned in front of them to the right. Participants were seated at a desk. The distance from the center of the screen to the eye was about 60 cm. Chin supports were not used, but during each session the postures of the participants were checked and corrected if their chests approached the screen or their backs were hunched.

Once an image was displayed on the left screen, on the answer screen to the right a bar consisting of seven small squares appeared, with the two opposed adjectives (in Italian) on each side. The subject had to click on the square indicating his or her degree of agreement with the two adjectives with regard to that image. For example, when considering the pair warm or cold, if a subject had maximum agreement with the word cold, she or he had to

Figure 1. Example of the stimulus (Ghiringhelli, *Composizione no 7*) presented in three different versions. Copyright MART—Archivio fotografico e mediateca.

Figure 2. Example of the stimulus (Soldati, *Idoli*) presented in three different versions. Copyright MART—Archivio fotografico e mediateca.

select the square nearest this word. When a subject considered the pair of adjectives "neutral" with respect to the image shown, she or he had to choose the central square. Once the choice was made by clicking on the square, the subject was instructed to hit "enter." Then the other three couples of opposed adjectives appeared, one at a time, according to the sequence just described. Only when all four judgments had been registered did the test move to the next image. To be noted is that the software stored the choice with two scores, one for each member of the couple. For example, if the subject selected the square nearest to the word "warm," a score of 7 was given to this adjective and a score of 1 was given to the adjective "cold." If the subject selected the second square nearest to the word "warm," a score of 6 was given to this adjective and a score of 2 was given to the adjective "cold." A similar procedure was applied for the third nearest square. Finally, if the subject selected the central square, a score of 4 was given to each adjective of the couple (Figure 3). Participants were allowed to change their choices at any time until they hit "enter" to proceed to the next choice. No

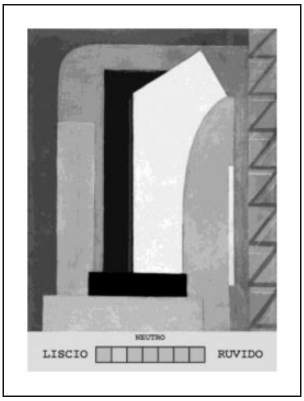

Figure 3. Example of the stimulus evaluation (Ghiringhelli, *Composizione no 7*) in black and white for the couple smooth or rough.

reaction time was requested, because the task was qualitative and phenomenologically based on subjective judgments in first person account.

Second Phase of the Experiment

Phase two of the experiments took place at the MART Museum, in the rooms of the exhibition. Here each subject had to evaluate only the 20 paintings that she or he had previously seen on the computer screen in the natural colors. The evaluation was carried out on a simple pen-and-paper form where small reproductions of the paintings with indications of their titles were printed with the 7-point evaluation scales positioned next to each photograph.

This facilitated easy identification of the works to rate. In both sessions, the subjects could use as much time as they felt was necessary to express a judgment.

Statistical Methods

To evaluate differences among the painting mean scores on each tactile dimension across the three color versions, three repeated measures analysis of variance (ANOVA) were performed (one for each tactile dimension). The comparison of the mean scores of the painting seen on a computer screen and at a museum setting was performed by means of the Student's test for paired data.

Results

First Phase of the Experiment

Table 1 shows the mean scores (and the standard deviations) of the pictures for each of the four adjectives and for each of the three color versions.

When the adjective ''warm'' was considered, a significant interaction was found between pictures and color versions ($F = 4.37$; $df = 118{,}1296$; $p < .001$). Therefore the differences among the means of the pictures were not constant across the three color versions and three separate ANOVAs were performed, one for each color version. Interestingly, when pictures seen in black and white were considered, nonsignificant difference among their mean scores was found ($F = 1.14$; $df = 59{,}426$; $p = 0.24$). On the other hand, the mean scores of the

Table 1. Means (*M*) and Standard Deviations (*SD*) of the scores given to 60 paintings according to the adjective and the color version.

	Natural colors		Inverted colors		Black and white	
	M	SD	M	SD	M	SD
Warm	4.23	1.72	3.10	1.70	3.03	1.57
Smooth	4.17	1.77	4.16	1.88	4.04	1.92
Lightweight	4.12	1.71	4.36	1.82	3.49	1.82
Soft	3.67	1.63	3.57	1.78	3.05	1.71

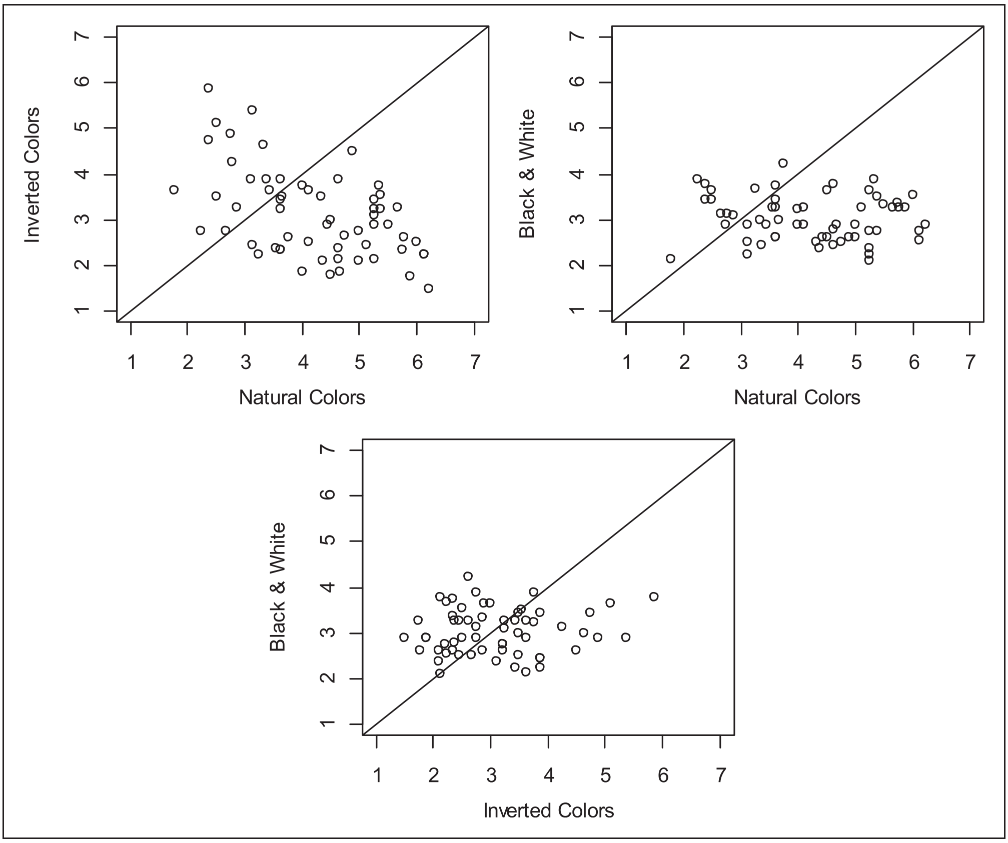

Figure 4. Scatterplots of the mean warmness ratings given to the 60 paintings when seen in natural colors, in inverted colors, and in black and white.

pictures were significantly different when seen both in natural colors ($F = 6.48$; $df = 59{,}416$; $p < .001$) and in inverted colors ($F = 4.47$; $df = 59{,}416$; $p < .001$). Figure 4 shows the scatterplots of the mean scores of the pictures according to color versions. Cold pictures in natural colors are warmed up when seen in inverted colors, while warm pictures in natural colors are cooled down when seen in inverted colors (Figure 4, panel a). On the other hand, warm pictures in natural colors are cooled down when seen in black and white, while cold

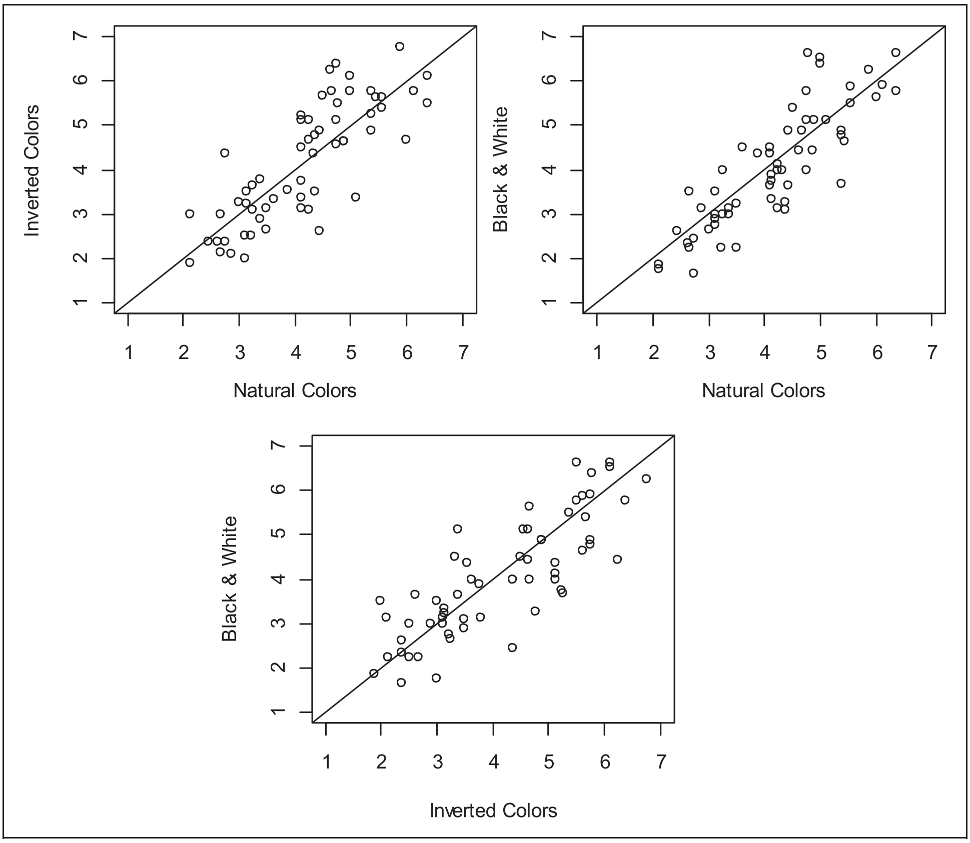

Figure 5. Scatterplots of the mean smoothness ratings given to the 60 paintings when seen in natural colors, in inverted colors, and in black and white.

pictures in natural colors remain, on average, cold when seen in black and white (Figure 4, panel b). A similar result holds for pictures seen in inverted colors (Figure 4, panel c). These patterns explain the highly significant interaction found in the ANOVA.

When the adjective "smooth" was considered, the interaction between pictures and color versions was not significant ($F = 1.12$; $df = 118,1296$; $p = .19$). Also the main effect of color version was not significant ($F = 1.30$; $df = 2,1296$; $p = .27$) so that the mean scores of the three color versions cannot be considered different. In other words, on the basis of these results, it was not possible rule out the hypothesis that the mean smoothness of the considered pictures was the same for (and therefore independent of) the three color versions. A significant difference was found as far as the main effect of the pictures is concerned ($F = 17.90$; $df = 59,1296$; $p < .001$). Figure 5 shows the scatterplots of the mean scores of the pictures according to color versions. The mean scores of the pictures range from about 2 to near the maximum score of 7.

When the adjective "lightweight" was considered, a significant interaction was found between pictures and color versions ($F = 1.91$; $df = 118,1296$; $p < .001$). Therefore the differences among the means of the pictures were not constant across the three color versions and three separate ANOVAs were performed, one for each color version. In this case, the mean scores of the pictures were significantly different when seen in natural colors ($F = 2.93$; $df = 59,416$; $p < .001$), in inverted colors ($F = 2.96$; $df = 59,416$; $p < .001$) and in black and white ($F = 3.31$; $df = 59,416$; $p < .001$). Figure 6 shows the scatterplots of the

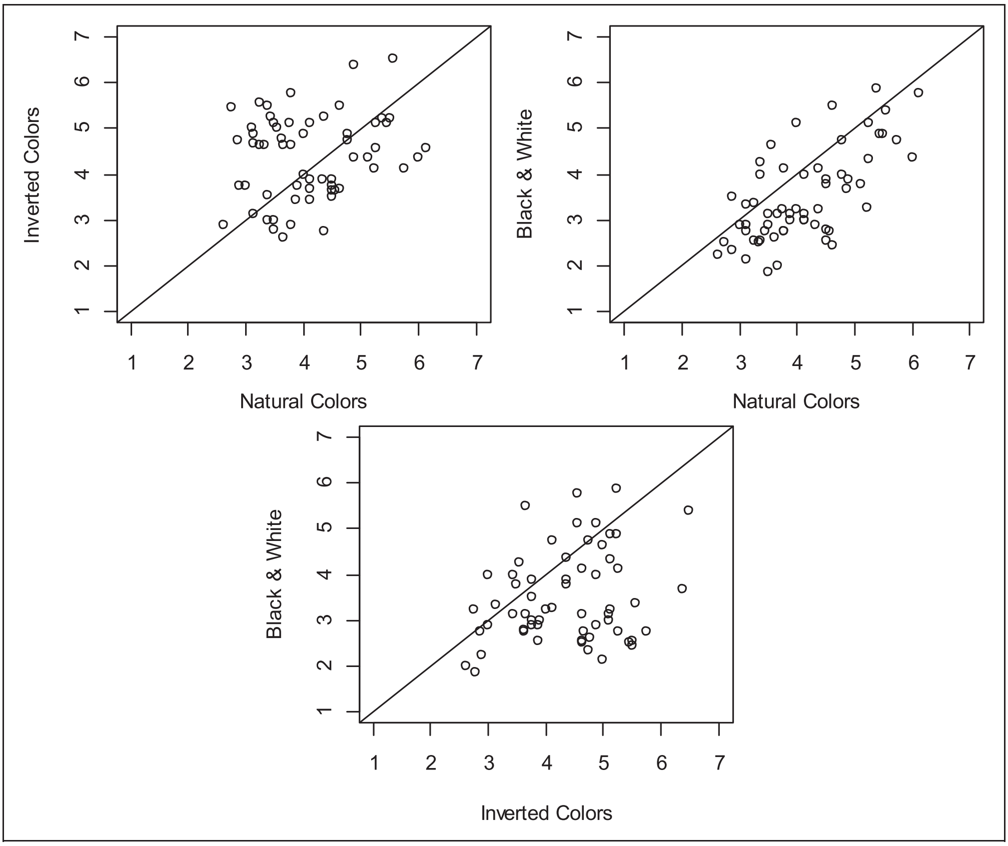

Figure 6. Scatterplots of the mean lightweight-ness ratings given to the 60 paintings when seen in natural colors, in inverted colors, and in black and white.

mean scores of the pictures according to color versions. The mean lightweight-ness of pictures seen in inverted colors appears substantially independent of that seen in natural colors (Figure 6, panel a). On the other hand, pictures seen in black and white are considered, on the average, less lightweight than when seen in natural colors; furthermore this finding is more evident for more lightweight pictures (Figure 6, panel b). A similar result holds for pictures seen in inverted colors (Figure 6, panel c). These patterns explain the significant interaction found in the ANOVA.

When the adjective "soft" was considered, the interaction between pictures and color versions was not significant ($F = 1.16$; $df = 118{,}1296$; $p = .13$). On the other hand, both the main effect of color version ($F = 23.48$; $df = 2{,}1296$; $p < .001$) and of the pictures ($F = 4.14$; $df = 59{,}1296$; $p < .001$) were significant. The mean "softness" of pictures seen in natural colors or in inverted colors can be considered quite similar (Figure 7, panel a and Table 1); on the other hand a reduction in the mean "softness" emerges when the pictures are seen in black and white (Figure 7, panels b and c and Table 1).

Second Phase of the Experiment

For each of the four adjectives, we calculated the mean value given by the subjects at each painting seen at the Mart museum and on a computer screen. Table 2 shows the mean scores

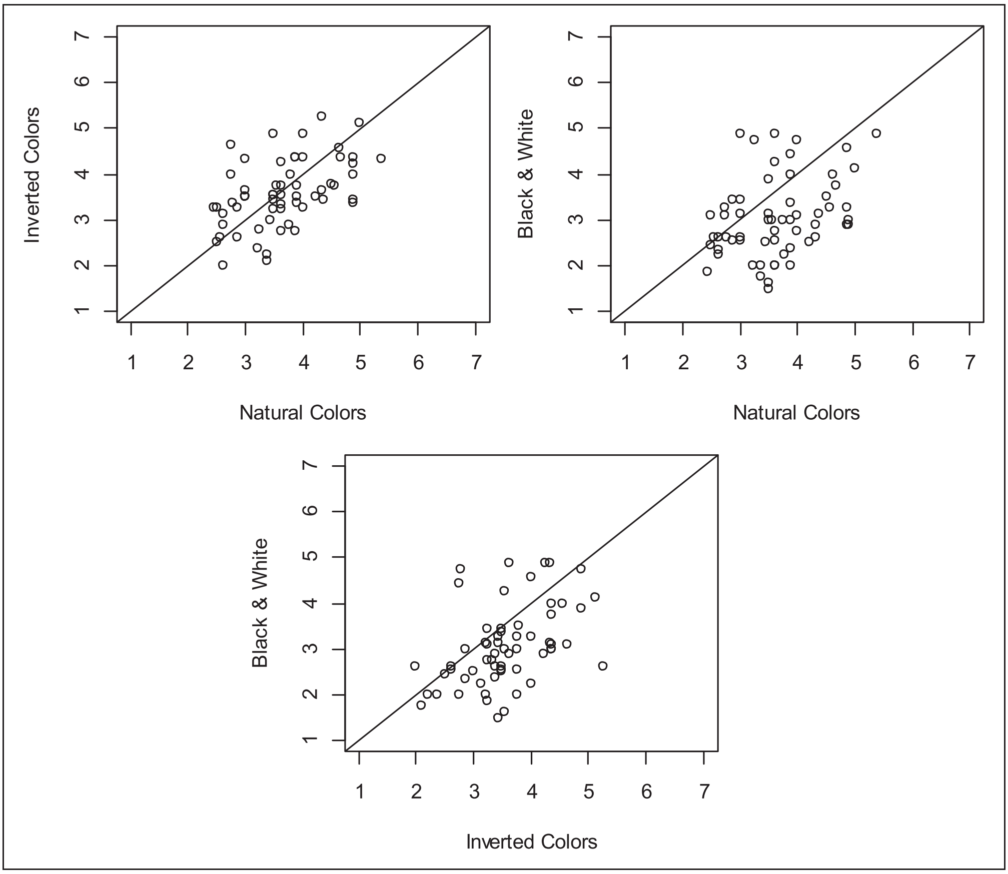

Figure 7. Scatterplots of the mean softness ratings given to the 60 paintings when seen in natural colors, in inverted colors, and in black and white.

Table 2. Comparison of the Scores Given to 60 Paintings When Seen on a Computer Screen or at the MART Museum.

	Computer screen		Mart museum			
	M	*SD*	*M*	*SD*	*t*	*p*
Warm	4.23	1.16	4.03	1.25	2.19	.033
Smooth	4.17	1.09	4.28	1.36	1.05	.297
Lightweight	4.12	0.88	4.18	0.96	0.67	.504
Soft	3.66	0.75	3.41	0.84	2.81	.007

(and the standard deviations) as well as the result of the statistical comparison. Both the mean smoothness and the mean lightweight-ness were not significantly different with respect to the two experimental conditions (Mart museum and computer screen). On the other hand, a significant result was found for the adjectives "warm" and "soft"; when seen at the Mart museum, on the average the paintings were less warm and less soft.

General Discussion

The experiment was conducted to test whether there exists a cross-modal association between the visual and tactile experience of abstract paintings by adult subjects. The results show that such associations do exist, although we could not have any empirical support, because of the nature of the stimuli. The results show that in some cases the associations depend on the color version. This is true in particular for the rating of temperature (warm or cold). As mentioned, Katz considered temperature to be the second most important source of tactile information, and he compared it to the perception of voluminousness in vision. Temperature was therefore confirmed to be a basic feature in cross-modal perception also in cases of very complex stimuli like abstract paintings. This should not come to a surprise. In fact, besides the role played by temperature in the field of objectual tactile perception, it is well known that in the field of cross-modal associations occurring in the general population, a perceptual attribute which proves to play an important role is color in both its denotative and connotative dimensions (among which the cold or warm dimension). In fact, it has been shown that color is associated with olfaction (Demattè, Sanabria, & Spence, 2006; Gilbert, Martin, & Kemp, 1996; Hanson-Vaux, Crisinel, & Spence, 2013; Kemp & Gilbert, 1997; Levitan et al., 2014), haptics (Ludwig & Simner, 2013), and acoustics (Moos, Simmons, Simner, & Smith, 2013; Moos, Smith, Miller, & Simmons, 2014; Ward et al., 2006). Recently, the association between color and shape has been experimentally tested by studies relating to Kandinsky's hypothesis of a systematic association between geometrical shapes and colors (Albertazzi, Canal et al., 2014; Albertazzi, Da Pos et al., 2013; Chen, Tanaka, & Watanabe, 2015; Jacobsen, 2002; Kharkhurin, 2012; Makin & Wuerger, 2013).

The highly significant interaction found analyzing the adjective "warm" indicates that natural or inverted colors strongly affect the cross-modal tactile perception of the paintings seen, since cold pictures in natural colors are warmed up when seen in inverted colors, while warm pictures in natural colors are cooled down when seen in inverted colors. When the same images were presented in black and white, the "warm" pictures were "cooled down," while those considered "cold" remained such. In other words, the temperature of images in white and black becomes uniform with cold. Again this should not be surprising. In fact, if some paintings are subjectively experienced, and hence evaluated as "cold" when seen in natural colors, it is very likely that the experienced attribute of "coldness" remains substantially the same also when the paintings are seen in black and white. Also in this case, the strong weight of the connotative dimension of temperature of color in perception is confirmed.

As far as the other tactile dimensions are concerned, the sensations evoked by the adjective "smooth" could be considered, overall, quite similar, independently of the three color versions since the three averages were almost the same and near the "neutral" value (i.e., 4). On the other hand, the ANOVA showed that different paintings are able to evoke different sensations of smoothness independently of the color version; these sensations vary nearly over the full range of the smoothness scale.

The color versions evoked different sensations on the remaining two tactile perceptions. In particular, as to the softness attribute, when seen in black and white, the pictures showed, on average, a systematic reduction in their softness. On the other hand, the adjective "lightweight" recorded more complex results. The mean lightweight-ness of pictures seen in inverted colors was substantially independent of that seen in natural colors, while pictures seen in black and white were considered, on average, less lightweight than when seen in natural colors (as well as when seen in inverted colors). Furthermore, this finding was more evident for more lightweight pictures. The diminished effect in pictures when seen in black and white may have been due to the exclusion of most of the several chromatic differences that play a role in the perceived "weight" of colors.

Finally, the experiment shows that some differences exist between the perception of images presented on a computer screen and the perception of the same paintings viewed in concrete at the museum, in regard to tactile dimensions such as "warm" and "soft": In these cases, in fact, the evaluations by the subjects of those dimensions were less extreme. The effect may have been due to the different textures of the stimuli as experienced in the two different modalities, since viewing a painting at first hand may afford more accuracy in the visual estimation of surface properties. The results in the field of cross-modality, as mentioned, suggest that there are attributes, within one modality or across different modalities, related by so-called natural biased associations, that is, ones not due to learning (Simner, Gartner et al., 2011; Simner, Lanz et al., 2005; Spector & Maurer, 2008, 2011). Notwithstanding the fact that studies in this field are increasing, a full-fledged explanatory theory has not yet been established. In our research, because of the kind of complex stimuli that we used (abstract paintings), one might explain the results in terms of cognitive associations beyond the standard sensory–sensory approach (Jürgens, & Nikolic, 2012; Mroczo-Wasowicz & Nikolić, 2014; Mroczko-Wasowicz & Werning, 2012; Sagiv, Ilbeigi, & Ben-Tal, 2011; Simner, 2012; Simner & Ward, 2006; Ward, 2013; Ward et al., 2007). Our experiment was divided into two phases in order to test the weight of the various factors responsible for the association. The first part involved an associative task based on visual characteristics perceived as associated with tactile ones. The second part was conducted in order to investigate the perceptual differences between two different modalities of presentation: on a computer screen or at first hand. The results did not show important changes in the perception of stimuli in two different modalities.

Future studies might focus on further dimensions of texture perception such as dry or wet or sticky or slippery; the subdimensions of macrocategories such as rough or smooth (Guest et al., 2011; Yoshida, 1968); or affective ones (dirty or clean). Furthermore, because of the nature of the stimuli, a study might test shape instead of texture, or both, and consequently make use of different couples of attributes such as angled or rounded, arched or straight, crooked or unbent, organized or messy, volumetric or flat, thin or thick. Research might be conducted on tactile perception and sound, associating the perceived tactile dimensions of our stimuli, such as roughness, with frequencies and musical timbre or affective dimensions of surfaces. Our hypothesis, however, is that the uniformity of style in our stimuli may be a not very informative factor in those associations. Future research can also be conducted to see whether the explanation we give for our results—that is, that the color connotative dimension of cold or warm is the major factor in the associations—is correct and can be eventually reinforced, for example, having a major number of subjects; or there might be evidence for further explanation besides what we give. Our study should be repeated with subjects from different cultures and with differing expertise, in order to determine whether the associations are confirmed and to what extent; or in cultures whose languages have a wider lexicon for tactile classifications. For example, in Italian and English, the lexicon for tactile perception is smaller and less differentiated than the lexicon for other sensory modalities (Ullmann, 1957). In other languages, matters may be different. A further development could be to test the association between the painting and other modalities, such as sound, taste, or smell (taking into account that adjectives referring to haptics do not usually transfer to dimensions of smell as in "warm odor"; Williams, 1976, p. 463).

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