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Original Study OS1(1-14)

Simple and complex images: Operationalization and first calibration

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Abstract

The aim of this study is to operationalize the construction of the complexity related to images. In particular, we want to calibrate the judgments of complexity related to colourful images and black and white images who belong to different categories (animals, fruit, transports, technological tools and faces) and examine the parameters related to the different levels of their categorical complexity.
The first part of this composition put forward a definition of the construction, a comparison between the various theories of the complexity of the images and an analysis of the various fields of application.
In the second part, the purpose is to operationalize the construction, together with the method, the procedures used, and the sample that are described in detail.
The article ends with a debate about the results and some thoughts about the importance to operationalize the construct of the complexity.
The added value of this study is to provide, for the first time, a contribution to the operationalization of the construct of complexity. The complex and simple images can be used by the scientific community as a catalog that could be used in different fields of application (for example clinical/experimental, marketing/advertising, etc.).

Key Words: complexity, operationalization, calibration, colorful images, black and white images

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Introduction

The ability to choose information from the surrounding environment with our sensory organs is the basis of human knowledge. This selection is controlled by endogenous processes, such as the individual's expectations, interests and purposes (1) and by exogenous processes related to the physical characteristics of the stimulus (2). Among the different characteristics of an exogenous nature, this study examines the complexity.

The literature investigating the mechanisms of the perception, which complying the visual complexity, is very restricted. According to Schmidt and Fleming, the reason is linked to the fact that underlying morphogenetic mechanisms are multiple and complex as well (3). This problem is also related to numerous definitions of complexity that have been provided by various researches

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by the time.

According to a general definition related to the study of complex systems, "complexity is the property of a system that can be modeled to show behaviors that are not all necessary, even if potentially anticipated by an intentional observer of this system" (4). Specifically, depending on the application, complexity was also defined as a computational complexity (5), complexity of nuisance (6), computer complexity or algorithmic complexity (7,8), effective complexity (6), complexity as a latent property (9), relational complexity (10) and ultimately statistical complexity (11,12).

In addition to the difficulty of reaching a single definition of the construction, there is another important issue: to understand if complexity can be considered as a general domain (and therefore trans-disciplinary) or as a specific construction domain (and therefore with properties, dimensions and different meanings, according to the different scientific perspectives). In this study, the suggested construction has been built in the specific domain perspective. Specifically, complexity is assessed in the evaluation of the visual representation of colorful and black and white images.

Historically, several researches have analyzed the construction of visual complexity and its effects on psychological processes. One of the very first experts who made a deal with complexity construction was Birkhoff (13). According to him, the pleasantness of the visual representation depends on the relationship between the "order" value and the "complexity" value ($M = O/C$). Furthermore, Birkhoff (13) has identified the measure of the complexity by an image with the number of its components. The object’s elementary components could be directly proportioned to the effort the observer makes to catch perceptively the structure. As well as the complexity, perception is a fact and it is related to the structure of the object and its elementary components (13).

This theory has two limitations: the attribution of subjective numeric values to the order and complexity parameters and the fact of being inclined to a greater extent for order and the simplicity penalizing the most complex configurations.

One of the main critics of Birkhoff's theory was Eysenck (14). He proposed a new formula in which the pleasantness of the visual representation does not depend on the relationship between order and complexity, but on the product of the two facts ($M = O \cdot C$) (14). Therefore, on the basis of this assumption, an image with a high degree of pleasantness must contain at the same time both elements of complexity and order, both fundamental structural features of the aesthetic experience (15). Another approach that has contributed to the study of complexity is that one of Berlyne (16). Berlyne, studying the hedonistic effects coming from the fluctuations of the arousal level, induced

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by a visual stimulation, believed that, what is complex, unexpected and contradictory, causes an high level of supervision. Specifically, he believes that the exploratory behavior of "stimulus research" is oriented towards some formal or structural characteristics of the stimulus itself, such as familiarity vs. novelty, monotony vs. surprise, simplicity vs. complexity, clarity vs. ambiguity and static vs. variability. Moreover, these characteristics, defined as "collative variables", are elements of perceptive conflict that lead to visual exploration and explain appreciation for new, complex and ambiguous stimulation (16). Preference towards complex stimulation over simple ones has also been investigated by Reber, Schwarz and Winkielman (17). They have hypothesized that the preference for complex stimulation depends on specific facts, such as expectations and attributions (complex stimuli create greatest expectations and attributions in the subject that increase the pleasantness of visual representation), perceptual fluidity (complex stimulation make an easier access to the meaning of the stimulus) and objective simplicity vs cognitive simplicity (complex stimuli have a great redundancy and are more easily recognized than simple stimulation) (17).

In recent times, Maeda (18), considering complexity and simplicity as two interconnected variables, says that complexity cannot exist without simplicity. According to him, the transition from simple to complex is a constant rhythm that marks the harmony with which these two dimensions intertwine in time and space. Therefore, according to Maeda, the term "complexity" can be understood only in relation to the word "simplicity". For this reason, complexity is in fact a multi-dimensional feature, dependent on the quantity of variables involved, their structure and intrinsic qualities (18). This perspective was recently confirmed also in the studies of Marin and Leder (19). According to them, complexity is the number and variety of the elements inside the visual representations (19).

Another researcher who contributed to the study of complexity was Birkin (20). He supposed that visual complexity can be defined by the following criteria: the level of detail (the various parts of an image), the number of colors (the variety of colors in the image), the redundancy (the order of an image), the amount of working (the difficulty of perceiving an image) and the depth (the three-dimensional perception) (20). The importance of color in the increase of the images complexity has also been studied by Massaro, Savazzi, Di Dio, Freedberg, Gallese, Gilli, &Marchetti (21).

In their research, the authors have found that color could enhance the effect of visual representation of some dynamic stimulation, enriching them with some perceptual details. This aspect may have, therefore, increased the complexity of the image (21).

In summary, the literature examined above shows that complexity of visual stimulation (colorful and black and white images) would seem to be linked to numerous facts (such as pleasure, order,

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color, number of parts, monotony, etc.) which would consequently influence the effects of complexity, such as the direction and duration of the exploratory responses, the psychophysiological indices, including the arousal (22), and the judgments of pleasure and preference (23,17).

The goals of the present study are:

a) operationalizing the construct of complexity related to some images. Specifically, the aim of this work is to create a questionnaire came from the coherences between the different authors on the definition of the images complexity.

1). The coherences emerged were: boredom, parts, connection of the parts, order, pleasure, colors and vividness of the colors;

b) analyzing the different levels of complexity of the images belonging to five categories (animals, fruit, transports, technological tools and faces);

c) providing to the scientific community a catalog of images with the related complexity index. In particular, we will calibrate and calibrate the complexity judgments related to colourful and black and white images belonging to five categories mentioned above.

Methods

Participants

The initial sample consisted of 250 students recruited in the Department of Cognitive Science, University of Messina. Only one hundred thirty seven undergraduates (M=67 e F=70) took part in this experiment. Their ages ranged from 19 to 25 years (M= 21,38; SD=±2,21).

The students attended to different degree courses and were contacted in different ways: at the end of the lessons, during the reception and by post.

Materials

Regarding the choice of material (a), in a first phase, the images (N=110) were found in some multimedia images catalogs (www.clipartgratis.it; www.openclipart.org). These images belonged to different categories, such as animals, fruit, transports, technological tools and faces. After this research, the images were judged by 16 independent observers who evaluated their degree of adherence to the category of membership. At the end of this phase, the images with high categorical representativeness were selected (stimulation recognized as belonging to the category at 96%). After this evaluation, the number of images was reduced to 35 (7 images for each category). In the next step, to create the same black and white images, the 35 images have been modified through two *Photoshop* adjustment filters (black and white adjustment and threshold reduction). The final material consisted of 70 images (35 in color form and 35 in black and white form). For the

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construction of the questionnaire (b), the questions were formulated referring to the specific criteria coming from the conceptualization of the complexity of some authors (Tab.1). Specifically, the questionnaire consists of subjective questions: how boring is the image? 2) how much do you think the image is ordered ?, 3) how much do you like the image?, and 4) how vivid are the colors inside the image? for color images and "how vivid are the image?" for black and white images; and objective questions:1) how many parts do you find in the image?) how connected are the parts?, and the last 3) how many colors are there in the image?. Moreover, to verify the consistency between the perceived complexity and each of the constancy emerged (boredom, parts, connection of the parts, order, pleasure, colors and vividness of the colors), the judgment of composite complexity was evaluated ("how complex is the 'image?").

Procedure

Participants were sat in front of an Apple computer in a quiet room. They were informed that they would be presented seventy images. Specifically, they should judge each image (N= 70 images) by answering eight questions. For each question, they would have given a score from 1 to 10. The task had an average duration of 60 minutes (about 1 minute for each image) and administered in a randomized and counterbalanced manner for each participant.

Tab. 1 - Indices for the conceptualization of complexity

AUTHORS	DATE	FEATURES OF COMPLEXITY
Birkhoff, G., D.	1932	• Pleasantness • Order
Eysenk, H., J.	1942	• Pleasantness • Order
Berlyne, D., E.	1974	• Familiarity vs novelty • Monotony vs surprise • Clarity vs ambiguity • Static vs variability • Simplicity
Boselie, F., & Leeuwenberg, E.	1984	• Beauty • No ambiguity of means • No ambiguity of ends • Bewilderment and surprise
Reber, R., Schwarz, N., Winkielman, P.	2004	• Attributions and expectations • Perceptive fluency • Objective simplicity vs cognitive simplicity
Maeda, J.	2006	• Simplicity
Birkin, G.	2010	• Parts • Colors • Order • Perspective effort • Depth
Massaro, D., Savazzi, F., Di Dio, C., Freedberg, D., Gallese, V., Gilli, G., Marchetti, A.	2012	• Colors
Marin, M., M., & Leder, H.	2013	• Number and variety of elements

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Results

The scores obtained in each question (score 8) for each image (N= 70) were calibrated in relation to all images. From calibration, the following criteria were excluded: "pleasure", as an item filler, "connection", as it is presented as a platicurtica and "color" and "vividness" distribution, as they showed a dichotomous distribution. After obtaining the scores, the sum of all the parameters was calculated to obtain the overall score related to the complexity of each image; the parameters relating to boredom (score 1) and to order (score 4) were inverted and then added together because they showed an inverse trend than the complexity parameter (Berlyne, 1974) (see Tab. 2 and tab. 3).

Evaluated the complexity of the category to which each image belonged, a drawing analysis of the variance of repeated measures was developed with two variables within the subjects (Type of images: colorful vs. black and white) x 5 (Categories: animals, fruit, transports, technological tools and faces), assuming the different criteria of complexity as dependent variables. To calculate the overall value of the complexity of each image, the following criteria were taken into consideration: boredom, parts and order.

About the global judgment concerning the boredom criteria, the variable type of the images shows significant effects, $F(1, 132) = 21.34$; $p < .0001$,this data indicates that black and white images of the five categories were judged to be more boring than colorful images.

The category variable also has significant effects, $F(4, 612) = 7.4$; $p < .0001$. The colorful and black and white images of the animal and fruit categories were judged to be less boring than the images of the other categories (transports, technological tools and faces) (Fig. 1)

Tab.2 Means and standard deviations (SD) of colorful and black and white images

	Animals	Fruit	Means of transport	Technological Tools	Faces
COLORFUL IMAGES	Fish -1,38 (-0.18)	Banana -2,56 (-0,81)	Scooter -1,08 (-0,13)	Computer -1,07 (-0,13)	Man 0,13 (0,03)
	Rabbit -0,71 (-0,10)	Strawberry -2,1 (-0,60)	Plane -0,97 (-0,12)	Camera -0,45 (-0,07)	Man -0,32 (-0,05)
	Dog -0,58 (-0,08)	Watermelon -0,86 (-0,11)	Car -0,46 (-0,07)	Stereo -0,53 (-0,08)	Man -0,30 (-0,05)
	Sheep -1,27 (-0,16)	Grapes -1,05 (-0,13)	Truck 0,43 (0,07)	Phone -0,52 (-0,08)	Woman -0,36 (-0,06)
	Deer -0,53 (-0,08)	Pineapple -1,47 (-0,20)	Bicycle -0,57 (-0,08)	Tv -0,98 (-0,12)	Woman -0,57 (-0,08)
	Cat -0,70 (-0,10)	Peach -1,72 (-0,30)	Motorcycle -0,28 (-0,05)	Video Camera 2,02 (0,57)	Woman 0,16 (0,04)
	Porcupine -0,65 (-0,09)	Cherry -1,86 (-0,41)	Bus -0,73 (-0,10)	Tablet -0,51 (-0,08)	Woman -0,53 (-0,08)
	Animals	**Fruit**	**Means of transport**	**Technological Tools**	**Faces**
BLACK AND WHITE IMAGES	Fish -1,08 (-0,13)	Banana -2,56 (-0,81)	Scooter -0,5 (-0.07)	Computer -0,28 (-0,05)	Man 0,13 (0,03)
	Rabbit -1,21 (-0,15)	Strawberry -0,11 (-0,03)	Plane -1,57 (-0,22)	Camera -0,37 (-0,06)	Man -1 (-0,13)
	Dog -1,12 (-0,14)	Watermelon -0,90 (-0,11)	Car 1,35 (0.18)	Stereo 0,06 (0,01)	Man -0,32 (-0,05)
	Sheep -0,62 (-0,08)	Grapes -0,66 (-0,08)	Truck 0,08 (0,02)	Phone -0,38 (-0,06)	Woman -0,90 (-0,11)
	Deer -0,82 (-0,11)	Pineapple -0,96 (-0,12)	Bicycle -0,26 (-0,05)	Tv –0,66 (-0,08)	Woman -0,28 (-0,05)
	Cat -1,01 (-0,13)	Peach -1,98 (-0,50)	Motorcycle 0,31 (0,05)	Video Camera -0,13 (-0,03)	Woman -0,16 (-0,04)
	Porcupine 0,78 (0,10)	Cherry -1,62 (-0,25)	Bus -1,37 (-0.18)	Tablet -1,35 (-0,18)	Woman -0,15 (-0,04)

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In relation to the overall judgment related to the order criterion, the variable type of images has significant effects, F (1,131) = 86, 85; p <.001. This data indicates that the colorful images of the five categories were judged to be more orderly than those in black and white. The category variable also has significant effects, F (4,612) = 5,31; p <.001. Specifically, the colorful images belonging to the technological tools category were judged more orderly than the colorful images (t (131) = 1.88; p <.005) (Fig. 2).

With regard to the overall judgment concerning the parts criterion, the variable type of images does not present significant effects. Although there were no statistically significant differences, colorful images of all categories were judged with more parts than black and white images. The category variable has significant effects, F (4, 612) = 3.83; p <.01. The data show that the images of the means of transport and face categories were judged with a large number of parts compared to the images (t (131) = 1.87; p <.007; t (131) = 1.85; p < .006) (Fig. 3).

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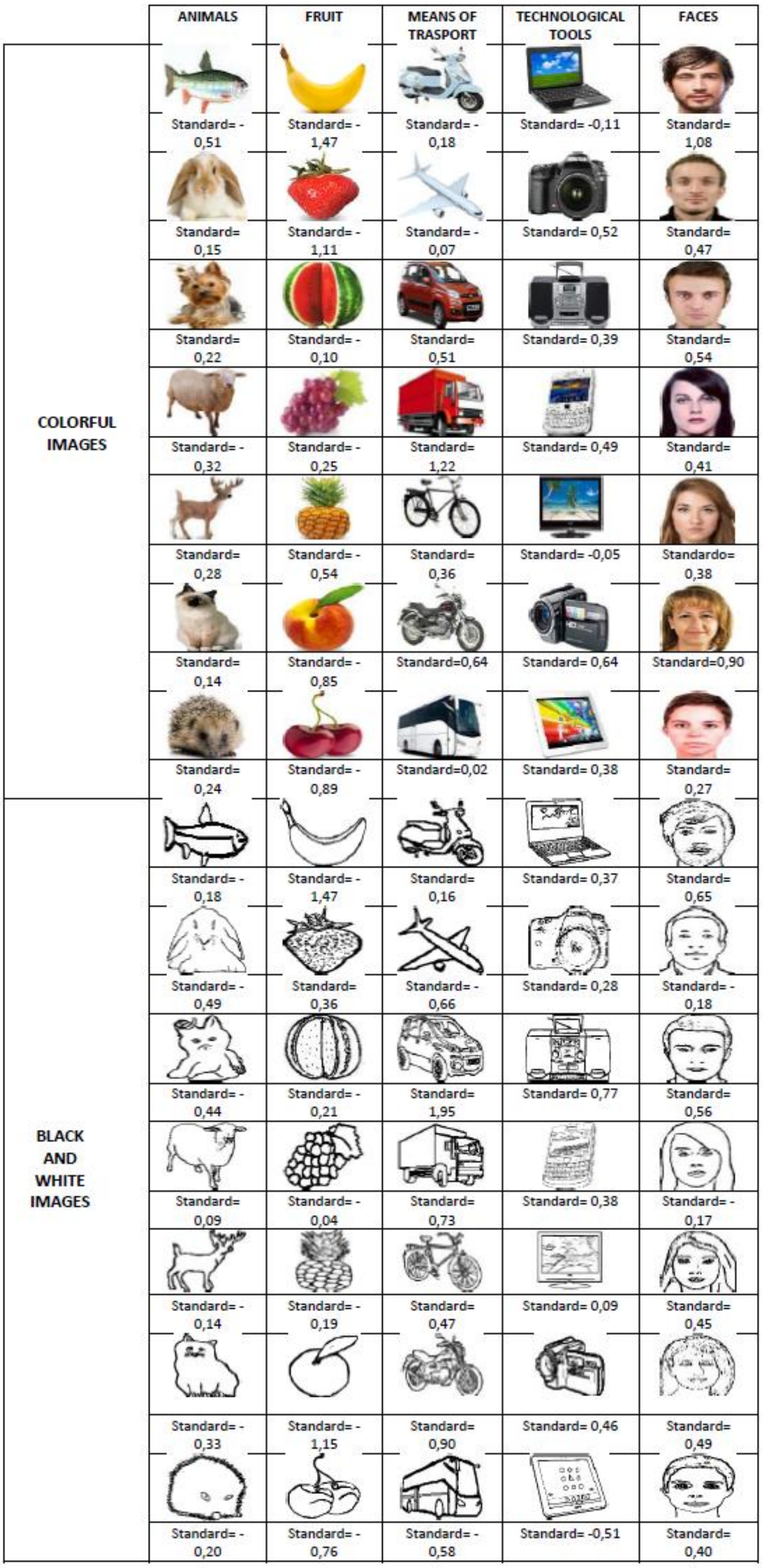

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Fig. 1.The colorful and black and white images of the animal and fruit categories were judged to be less boring than the images of the other categories (transports, technological tools and faces)

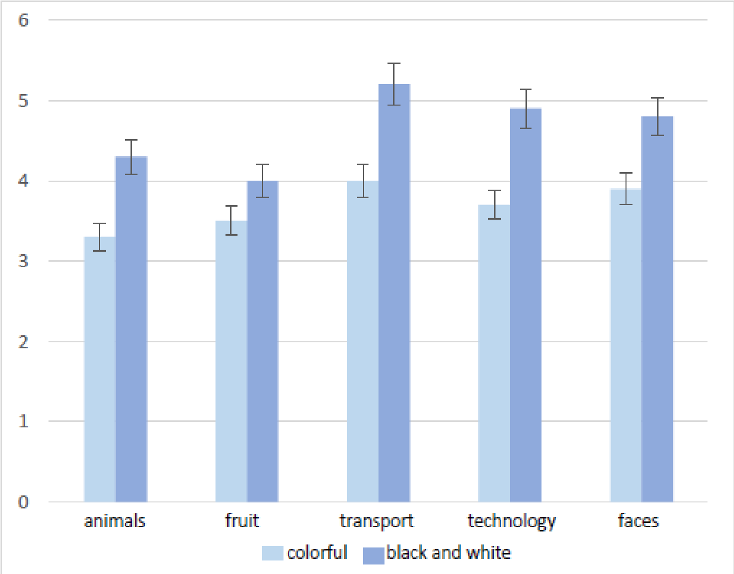

Fig.2 Averages and standard deviations related to the order criterion

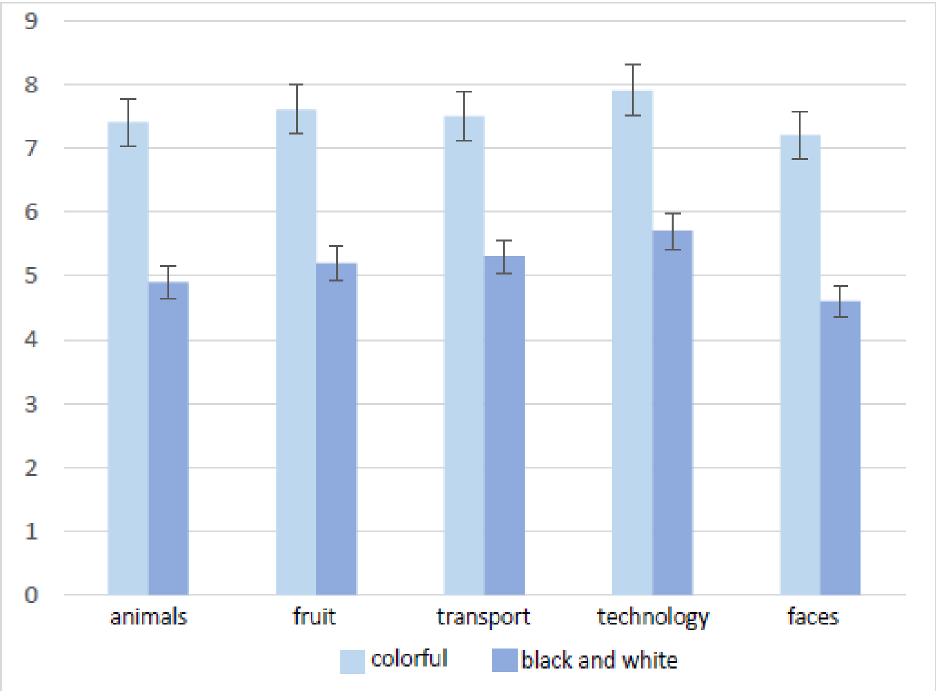

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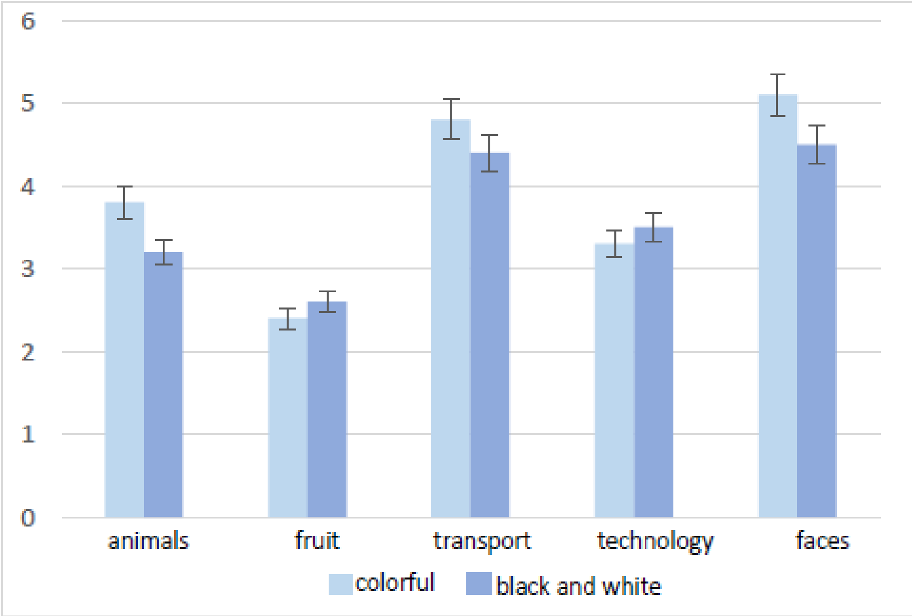
Fig.3 Averages and standard deviations related to the parts criterion



For each image (N=70), the results relative to each of the three criteria (boredom, parts and order) were related to the complexity judgment of the single images (question: "how complex is the image?").

The application of the coefficients showed that the boredom parameter and the complexity parameter correlating significantly andnegatively, r (136)= -.36, p<.01. The parts and the complexity parameter correlate significantly and positively, r (136)= .47, p<.01 . Finally, the order parameter and the complexity parameter correlate significantly and negatively, r (136)= -.51, p<.01. The correlation's levels show a trend compatible with the definition of the criteria.

Adding the three parameters, it has been obtained a global judgment on the complexity criteria. Referring to this composite parameter, the variable type of images is not showing significant effects.

This data indicates that the judgment of composite complexity does not seem to be related to the fact that an image is colorful or in black and white. Instead, the category variable shows significant effects, F (4, 621) = 8.27; p <.05. Specifically, the images related to transports, technological tools and faces categories were judged to be more complex than the other categories F (4, 612) = 4.03; p <.01 (Fig.4).

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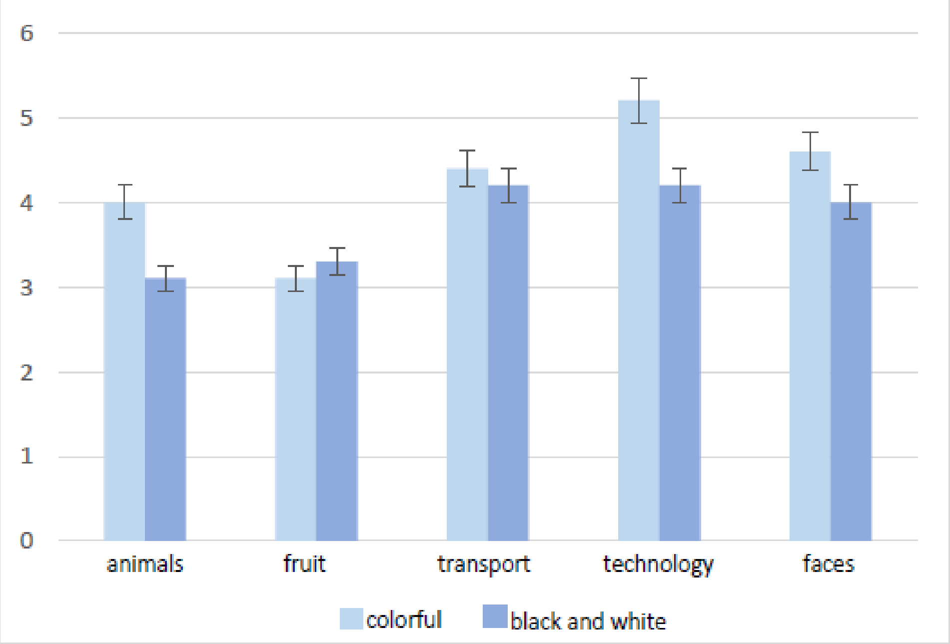
Fig.4 Averages and standard deviations related to composite parameter



Discussion

The most important aim of this work was to provide to the scientific community a contribution for the operationalization of the complexity construct related to colorful and black and white images. As it has emerged in the introduction, the construction is not linear and there is currently not a review delineating a view commonly accepted by researchers who deal with complexity.

First of all, a basic question is to understand if complexity can be considered as a general domain (and therefore trans-disciplinary) or as a specific domain construction (and therefore with different properties, dimensions and meanings according to different scientific perspectives). In this study, the second perspective (specific domain) has been highly considerated. Specifically, after an analysis of the literature about complexity of the images, it has been created a questionnaire, referring to the coherences emerged among the different authors about the definition of the images complexity (Tab.1). Moreover, in order to verify the consistency between the perceived complexity and each of the constancy emerged (boredom, parts, connection of the parts, order, pleasure, colors and vividness of the colors), it has been evaluated the judgment of composite complexity as well.

Another goal of the study was to analyze the different levels of complexity of the categories belonging to the images (animals, fruits, means of transport, technological tools and faces). The data shows that the images of transports, technologies and faces categories were judged to be more complex than the other categories. Furthermore, the complexity judgment (consisting in the boredom, the number of parts and the order criteria) does not seem to be related to the fact that an image is in color or in black and white.

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The last goal of this composition was to provide to the scientific community a catalog of colorful and black and white images (check the following link https://github.com) with all of complexity index. This catalog could be used in different fields of application (for example clinical/experimental, marketing/advertising, etc.). As for the clinical/experimental area, this catalog could be useful to all those researchers who, through the administration of simple and complex images, would investigate the visual response of subjects with different pathologies, such as Developmental Delayes, Autism Spectrum Disorder and Rett Syndrome (24,25,26,27,28,29,30,31,32), and also Specific Disorders of the Learning, Attention Deficit and Hyperactivity (33,34,35,36,37,38). This aspect could be interesting for clinical and therapeutic implications. With regarding to clinical aspect, knowledge how individuals, under different sensory stimulation conditions, perceive simple and complex images could allow to investigate and study the specific difficulties of certain pathologies and also to understand the consequences that these difficulties might have on important cognitive functions (such as attention and memory). Moreover, from a therapeutic point of view, this knowledge could have important consequences for the setting of therapeutic work (such as the intervention, the areas to be strengthened and which methodology to use based on the difficulties and the functioning of the subject). For example, all the forms of hierarchical learning models have been developed to show to the intellectual disabled patients before simple and after complex stimuli; in this way they can learn more easily. Hierarchical learning models have been applied to a diverse range of practical tasks with much success.

In relation to the other domain, the marketing and advertising ones, this catalog of images could be useful for those researchers who would like to evaluate how the complexity of visual stimulation (for example images, photos, logos, advertising products, etc.) can influence consumers. This aspect could be very useful to understand the reason why, for example, some complex logos are recognized faster than simple ones (39).

The current study has some limitations. First, we included only five categories of objects. So, it could be interesting to evaluate the complexity of other categories (not only concrete objects but also abstract forms, such as geometric figures). Second, we considered only two fields of application (for example clinical/experimental, marketing/advertising, etc). It would be interesting to understand how this catalog could be used in other field (such as technological, artistic). The age of the sample and the small size are also to be considered limitations.

As a conclusion, given the importance and the weight that complexity assumes on the individual's cognitive processes (attention, memory, learning), future research should be focused their attention on the following aspects: a) the refinement of existing measurement tools and the creation of new ones

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inspired by an interdisciplinary approach to complexity; b) the study of simple and complex stimulation coming from other sensory domains (eg. auditory domains); c) the evaluation of simple and complex images both static and dynamic and, finally, d) the analysis of the complexity in subjects of different ages (adolescent and adult age) with typical and atypical development.

Conflict of interest: The Authors declare non conflict of interest

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