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The Value of Using Hypothesis-Testing Research for Graphic Design: Do decorative pictures contribute to learning?

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Abstract

Graphic design as an academic and research practice is relatively young when compared to the established disciplines such as education, psychology, medicine, and history. It was only community-type colleges and technical institutions that offered design as a vocational trade. Universities in South Africa started to offer design in the latter half of the twentieth century. It is only in the last two decades that we have seen design research output in South Africa. The relatively low number of international design journals when compared to education, for example, attest to the young scientific discipline of research in design. New media and the exponential growth in the digital forms of communication, education, training, and marketing have created an overlap between design, information technology, education, communication, and marketing. Graphic design research is no longer a discipline that is solely driven by theoretical frameworks and reliant on descriptive and qualitative research methods. Research in graphic design overlaps with other scientific practices and should embrace their research methods. One such method is hypothesis-testing research. This method allows for the comparison of values between groups and for the calculation of the effect size of a design variable. Hypothesis-testing research is a quantifiable process that enables a design researcher to determine objectively whether a design intervention makes an improvement and allows for the quantification of this improvement. This paper reports on a hypothesis-testing study that questions the use of decorative material as a variable to improve learning. We will further illustrate the value of this method by demonstrating the use of inferential statistics to calculate the effect size of the decorative graphic that is supposed to improve learning. We conclude by arguing that the adoption of enquiring methods nestled in other academic disciplines will add value to research in the design disciplines.

Keywords: Hypothesis-testing research, pictures, learning, decorative pictures

Introduction

Graphic design as an academic and research practice is relatively young when compared to the established disciplines such as education, psychology, medicine, and history. It was only community colleges and technical institutions that offered design as a vocational trade. Universities in South Africa started to offer design in the latter half of the twentieth century. It is only in the last two decades that we have seen design research output in South Africa. The relatively low numbers of international design journals when compared to education, for example, attest to the young scientific discipline of research in design. New media and the exponential growth in the digital forms of communication, education, and training, and marketing have created an overlap between design, information technology, education, communication and marketing. Graphic design research is no longer a discipline that is solely driven by theoretical frameworks and reliant on descriptive and qualitative research methods. Research in graphic design overlaps with other scientific practices and should embrace their research methods. One such method is inferential statistics and hypothesis-testing research. This method allows for the comparison of values between groups and for the calculation of the effect size of a design variable. Hypothesis-testing research is a quantifiable process that enables a design researcher to determine objectively whether a design intervention makes an improvement and allows for the quantification of this improvement.

The aim of this paper is to provide an overview of the hypothesis-testing method, its application in a design research project, and the value it holds for future design projects. When used in conjunction with learning material, research results about the effectiveness of decorative pictures appear to be inconsistent. Scholars use various terms when they refer to such images in learning material. Some of these terms overlap and may create some uncertainty. We tabulated these terms with their meaning at the end of this paper.

The results of earlier paper-based studies conducted from the 1970s through to the 1980s indicate that irrelevant elements in learning material such as decorative material, do not contribute to learning. Current digitally based studies suggest that decorative graphics may contribute to learning. Our experiment tested the results of recent studies that reported that decorative graphics in learning material may facilitate the learning process (Schneider, Nebel and Rey 2016; Mayer & Estrella 2014; Plass, Heidig, Hayward, Homer & Um 2014; Um, Plass, Hayward & Homer 2012). These authors used the term ‘positive emotional graphics’ to describe what we as graphic designers, would describe as ‘decorative graphics’. These results appear to contradict the earlier work of scholars (Levin & Lesgold 1978; Levin 1981; Levie & Lentz 1982; Digdon, Pressley & Levin 1985; Levin, Anglin & Carney 1987) that worked in the field of visual literacy, and in particular, those that looked at the use of imagery in learning material as an agent to improve learning. The results of the more recent studies seem to suggest that some decorative graphics, and when used with learning material, can contribute to improved learning. The term ‘decorative graphics’ in this context, has a similar meaning to the terms’ aesthetically appealing design’ (Plass et al. 2014), ‘emotional design’ (Mayer & Estrella 2014), and ‘positive emotional design’ (Schneider et al. 2016; Um et al. 2012).

In the present experiment, the lesson was about radiation therapy, where the decorative graphics included the use of comic-like graphics. We added an element of humour to the graphics and added some sound bubbles. Rey (2012 & 2014) argues that learners view these briefly and that they may have little or no effect on their learning performance. Our experiment tested the hypothesis that decorative graphics contribute to the learning process.

The objective and framework

Earlier work done, mainly in the education and psychology fields, indicates that text-relevant pictures (but not decorative pictures), facilitate the comprehension and recall of information that is presented in printed learning material (Levin & Lesgold 1978; Levin 1981; Levie & Lentz 1982; Digdon, Pressley & Levin 1985; Levin, Anglin & Carney 1987). The educational effect of pictures in explanative picture-text material can be of impressive magnitude. An increase, for example, of more than 50% in problem-solving transfer and retention of concepts is reported by Mayer (1993) when explanative illustrations are used with explanative text, when the learners have low prior knowledge of the material, and when the test criteria measure conceptual retention and problem-solving transfer skills. The work of Mayer is based on 24 published experiments that were completed over a period of twenty years. A moderate facilitating effect of between 11% and 15% is reported by Anglin (1987), who used prose and representational pictures. The facilitating effect is normally higher with explanative pictures than with representational pictures. Levie and Lentz (1982) give a mean improvement of 36% for groups reading text with pictures when compared to groups that read text alone. They based their results on a review of 23 studies that produced 46 comparisons. A frequently quoted review by Levin and Lesgold (1978, p. 233) found that pictures produce a consistent increase in comprehension during prose learning. Pictures are beneficial if the subjects are children; if they listen to a narrative prose passage; when the pictures overlap the prose content, and when testing is on factual content. Later studies looked at multimedia and animation as agents to learning reported similar facilitating effects. Two good examples are the work of Höffler and Leutner (2007), as well as Bello-Bravo, Olana and Pittendrigh (2015). The meta-analysis of a series of 26 studies by Höffler and Leutner have shown that instructional animations are more effective when they are representational, highly realistic and when the material to be learned relates to the motion, trajectory or change over time depicted by the animation.

Decorative pictures (text-irrelevant imagery) in learning material are graphics that prettify the text material. Researchers have described decorative pictures in different ways. Decorative pictures are non-instructional but aesthetically pleasing. They are used to appeal to one's emotions, whereas instructional pictures are informative in nature, relate to the text and exemplify the learning material. Schneider et al. (2016) place decorative graphics in two separate categories, namely seductive decorative pictures and conducive decorative pictures. Seductive decorative pictures consist of irrelevant but interesting learning material, while conducive decorative pictures may increase learning through mediating factors like positive emotions or interest.

Several authors have reported that decorative material, and in particular pictures and graphic decorations that are not relevant to the learning material, do not contribute to an increase in comprehension or recall (Levin 1981; Levie & Lentz 1982; Levin et al. 1987; Mayer 1993). Later work by Sung and Mayer (2012) has also shown that decorative graphics that are added to text do not add to the learning process. A shortcoming of a number of the earlier studies cited above, at least from a graphic designer's perspective, is that the pictures that the scholars used in the experiments were mostly without imagination and in monochrome. Even though later multimedia and animation experiments contain colour, the pictures and graphic were at a basic level in terms of artistic impression.

Pictures and emotions

Scholars have also reported that illustrations can foster learning through an effective process (Lowe 2004; Schnotz & Rasch 2005). Illustrations can have an emotional function whereby they have the power to engage, attract attention and motivate a learner. This function is similar to

that of animations produced for the advertising and entertainment industries. Illustrations with an emotional function, and that do not relate to the textual learning material would typically fall in the decorative picture typology of Levin (1981; 1989).

Um et al. (2012) posed the question of whether one can structure a multimedia learning environment in such a manner that it fosters positive emotions and whether such positive emotions can improve learning. They used 118 American college students and randomly assigned them to four treatment conditions in a 2x2 factorial design. The variables consisted of an external induction to create positive or neutral emotions with the learners, and an internal induction of emotions through what they describe as positive or neutral emotional graphics. The terms positive and neutral emotional graphics require some explanation at this point. Both the positive and neutral 'emotional' graphics are, from a designer's perspective, merely decorative material. The graphics do not contain learning content but are graphics that supplement the learning material through decorative means. The positive graphics are in colour with smiling faces, while the neutral graphics are monochrome without smiling faces. The work of Um et al. (2012) has shown that the graphics designed to create positive emotions reduced the perceived difficulty of the learning material. The positive emotional graphics increased learners' comprehension and transfer scores, while the external mood-induction procedure only improved the learners' transfer scores. Plass et al. (2014) sought to replicate Um's results by using a different sample (112 German graduate students) and by using the same experimental material and process. Their results were similar to the study by Um et al. (2012) in that subjects that received the positive emotional learning material performed better with a comprehension test than those that received neutral emotional graphics with their learning material. Their results have shown that both colour and shape contribute to an increase in comprehension.

Mayer and Estrella (2014) investigated whether the inclusion of emotional design features to multimedia improves learning outcomes. They conducted two small experiments (n = 64 in the first, and n = 45 in the second experiment) where the subjects either received learning material with enhanced graphics or neutral (non-enhanced) graphics. Their graphics in their experimental groups were similar to the positive emotional graphics in the studies by Um et al. (2012) and Plass et al. (2014), in that the cells in their lesson are in colour and are given human-like characteristics. Their findings suggest that emotional graphics (colour decorative graphics with smiling faces) do contribute to the success of learning material, particularly if they are relevant and do not include information that might confuse the user. Participants who received positive emotional graphics performed better in the first experiment, as well as the second experiment in terms of their total retention and transfer test scores.

From an illustrator and design perspective, we have to highlight a few issues about the pictures that the above scholars used in their experiments. The pictures in the experiments of Um et al. (2012) and Plass et al. (2014) consisted of graphic shapes that explained how a human being's immune system works. These pictures consisted of either basic geometric outline shapes filled with a grey colour, or the same shape filled with colour, on against a coloured background. The colour graphics are given human-like characteristics in that eyes and mouths were scrawled on the graphics. The pictures in Mayer and Estrella's (2014) work are similar. Their neutral graphics consisted of monochrome graphic shapes, while their positive graphics were the same shape, except that they were in colour and contained a simplified human face. Although Mayer and Estrella (2014) described these images as neutral or positive emotional graphics, they are in essence somewhere in between the interpretive and transformational pictures classification as proposed by Levin (1981; 1989). These graphics will help a learner to associate and visualise technical terms with memorable shapes. The graphics will also help a learner follow the process described with the text and assist with subsequent recall.

The experiment

We questioned the results of Mayer and Estrella (2014), Um et al. (2012) and Plass et al. (2014) because the results are in conflict with the earlier results of Levin (1981), Levie and Lentz (1982), Levin et al. (1987) and Mayer (1993) who reported no learning facilitation for decorative pictures. We tested the hypothesis that decorative pictures may facilitate learning by conducting an experiment aimed to expand the work by Plass et al. (2014), Mayer and Estrella (2014) and Um et al. (2012). The strategy was to induce positive emotions and to increase a motivational aspect with graphics. For this, we used a comic-book approach and as with the above studies, the personification of the graphics for one of the experimental groups. We hypothesised that positive emotional graphics in animated learning material would improve learning more than the animated material with neutral graphics, and more than static material with positive, and static material with neutral graphics. The experiment was similar in design as the one conducted by Mayer and Estrella (2014), except that the graphics formed a larger visual component of the learning material, and we also introduced a higher level of visual aesthetics than the experiments by Um et al. (2012) and Plass et al. (2014).

Participants and design

The participants consisted of 231 secondary school learners in their tenth and eleventh year of schooling. They were recruited from two schools in Bloemfontein in the Free State province of South Africa. One school was situated in a middle-income suburb while the second school was situated in a lower-income suburb. There were 118 boys, and 113 girls and their ages ranged between 14 and 19 years. Of these, 9.4% were in the 14–15 year age group, 74.4% were in the 16–17 year age group and 15% were in the 17–19 year age group. Compulsory schooling in South African consists of seven years in a primary school and five years in a secondary school. Participation was voluntary, and subjects were not promised any reward. The Free State Department of Education and the two schools gave permission to recruit learners for the experiment. Participants who were younger than 18 years old obtained permission from their parents. The research was conducted after receiving ethical approval for the study. The university's Ethics Committee clearance number is SCRE/2014/11/004.

A small pilot study tested the procedure with five subjects prior to commencing with the experiment. There were no noticeable procedural difficulties with the material delivery process and answer collection process. The pilot test subjects did not report any difficulties with the level of the learning material or comprehending the questions.

The experiment consisted of a pre-test, post-test design, with four different treatments in the post-test. Subjects were randomly allocated to one of four treatment groups, and placed in front of a computer workstation in a computer laboratory. A facilitator demonstrated the procedure on a screen after which the learners were instructed to complete the pre-test. Pupils received the learning material via a computer and then completed an on-line questionnaire. The pre-test consisted of a 486-word, seven-slide presentation about keys to safer food. The material came from the World Health Organization (WHO 2014) and explained in five steps what one must do to prevent foodborne diseases. Five graphics next to the text augmented these steps, for example, the process of keeping raw food away from cooked food. Ten multiple-choice questions tested the learners' knowledge of the aforementioned learning material. The pre-test was a self-paced process and learners had control to go back to previous slides. The purpose of the pre-test was to determine if there is a significant difference between the groups in terms of tests score of unrelated learning material delivered through a computerised system and an on-line comprehension questionnaire. A significant difference in the pre-test scores will enable one to control for any difference between the ability of the four groups. Even though a random allocation to different treatment groups should theoretically

provide equivalent groups in terms of ability, there is always the probability that one group by chance may contain a disproportion of subjects with lower or higher ability. This would cause a treatment group to show a higher score, not due to the treatment variable.

The procedure for the post-test was similar to the pre-test except that each group received a different treatment. The material for the first group, the Animation Positive (AP) was multimedia learning material in an animated format, designed to induce positive emotions. The material consisted of the learning material in text format and included comic-like motion graphics and characters, sound bubbles, and anthropomorphic images of cancer cells. The second group, the Animation Neutral (AN) group received the same material in the same format, except that the images of the cancer cells were no longer anthropomorphic but consisted of graphic shapes. The material for the third and fourth group, the Static Positive (SP) and the Static Neutral (SN) groups were the same as for the animated groups, except that the multimedia material was static and consisted of six still pages. The material for all four groups was self-paced, and students could go back or forward at their own will. All the learners completed the experiment in 45 minutes. Each student received a small fruit juice after completion of the experiment.

The instructional material

The text material for the post-test consisted of 410 words about radiation therapy and its treatment for cancer compiled from information available from the National Breast Cancer Foundation, Inc. (2012) and the National Cancer Institute at the National Institutes of Health (2009). The reason for choosing radiation therapy as a topic is that it is not a common subject at school. Using this topic for the learning material would eliminate prior knowledge, as learners are not likely to have prior knowledge about this topic. Prior knowledge is a variable that would have unduly influenced the post-test scores of the learners.

A section of the post-test learning material and the associated multiple-choice question is provided below.

Radiation therapy, sometimes called radiotherapy, is a procedure that treats certain forms of cancer to kill cancer cells or control their growth. A doctor called a radiation oncologist oversees radiation therapy, which usually consists of a specific number of treatments given over a specific time.

Question: What is the role of radiation oncologist?

a) The doctor who will oversee the care of each person undergoing radiation treatment.
b) The doctor who typically create the radiation beam during radiation therapy treatments.
c) A medical specialist who practices surgery.
d) None of the above

Data analysis

The independent variables under investigation were the subjects' comprehension of the learning material while the dependent variables were positive graphic elements in an animated and in a static format, aimed to elicit a positive emotional response. We determined whether the data was normally distributed by using the Levene Statistic to check the variability, the Welsch ANOVA and the Games-Howell post-hoc test to determine if one treatment is better than another, to establish if positive graphic elements in learning material could contribute to better learning.

The results

The results of the pre-test and the post-test for the four treatment groups are provided below.

The pre-test results

A Normal Q-Q plot of the pre-test scores indicated that the scores were approximately normally distributed. However, the Levene F-test indicated that the post-test variances were not equal, F(3, 224) = 10.24, p = .000. It is because of the lack of homogeneity of variances that we used the Welch ANOVA to test if there was a difference between the means of the four pre-test scores. The results indicate that there were no significant statistical differences between the group means, F(3, 123.33) = 1.97, p = .122. There would thus not be a rationale for controlling the pre-test scores in the analyses of the post-test scores.

The post-test results

A Normal Q-Q plot of the post-test scores indicated that the scores were approximately normally distributed. As with the pre-test results, a Levene's F-test showed that the post-test variances were also not equal, *F(3, 227) = 2.86, p = .038*. A Welch ANOVA indicated that there was a difference between the means of the four post-test scores*, F(3, 124.76) = 11.69, p = .000.* Since the assumption of homogeneity of variances was violated, the Games-Howell post-hoc test was used to determine which post-test scores were significantly different between the treatment groups.

There was a significant difference (p = .024, d = .538) between the mean of the Positive Animation (PA) group (M = 3.65, SD = 1.06) and the mean of the Neutral Animation (NA) group (M = 3.16, SD = .727). Students in the Positive Static group (M = 4.11, SD = .976) also scored significantly better (p = .000, d = 1.099) than the Neutral Animation (NA) group (M = 3.16, SD = .727) and significantly better (p = .006, d = .626) than the Neutral Static (NS) group (M = 3.53, SD = .873). The descriptive statistics for the post-test are provided in Table 1, and the results of the Games-Howell post-hoc test are provided in Table 2.

Table 1. The Means and Standard Deviations for each group on comprehension

	n	***M***	***SD***
Animation (Positive)	57	3.65	1.06
Animation (Neutral)	57	3.16	.73
Static (Positive)	57	4.11	.98
Static (Neutral)	60	3.53	.87

Table 2. The results of the Games-Howell Post-Hoc Test by treatment

Treatment groups	***M***	**Mean differences**			
		Animation (Positive)	**Animation (Neutral)**	**Static (Positive)**	**Static (Neutral)**
Animation (Positive)	3.65	--			
Animation (Neutral)	3.16	.491* (d = .538)	--		

Static (Positive)	4.11	-.456	-0.947** (*d* = 1.099)	--	
Static (Neutral)	3.53	.116	-.375	.571* (*d* = .626)	--

*p < .05; **p < .001

Influence of school and level of the learners

We further analysed the data to determine if the school (one from a middle-income, the other a lower-income environment), or if the level of schooling (Grade 10 and Grade 11) influenced the results.

In terms of the different schools, a Normal Q-Q plot indicated that the data for the participants who were in the animation groups from the two schools were normally distributed. There was homogeneity of variance, as assessed by Levene's test for equality of variances, *F(7, 223) = 2.00, p = 0.056.* A two-way ANOVA showed that there was no statistically significant interaction between the animation groups of the two schools for the post-test scores, *F(3, 231) = 1.081, p = .358,* partial $\eta^2 = .014$.

In terms of the different school grades, a Normal Q-Q plot indicated that the data for the participants that were in the animation groups and in the two different grade levels were normally distributed. There was also homogeneity of variance, *F(7, 223) = 1.43, p = .195*. A two-way ANOVA showed that there was a statistically significant interaction between the animation groups and grade levels for the post-test scores, *F(3, 223) = 3.117, p = .027*, partial $\eta^2 = .04$. A univariate test on the influence of animation groups on the post-test scores for students in Grade 10 and Grade 11 indicated that there was not a significant statistical difference in post-test scores between the different animation groups for learners in Grade 10, *F(3,223)=2.418, p = 0.067,* $\eta^2=0.032$. However, there was a significant difference in post-test scores between participants in different animation groups for participants in Grade 11, *F(3, 223) = 11.943, p = 0.000,* $\eta^2 = .138$. Pairwise comparison for Grade 11 learners indicated a significant difference in post-test scores for Grade 11 participants in the Animation (Positive) group and participants in the Animation (Neutral) group. Grade 11 participants in the Animation (Positive) group had higher mean post-test scores *(M = 4.04)* than Grade 11 participants in the Animation (Neutral) group *(M = 3.16)*. There was also a significant difference in post-test scores between the Animation (Neutral) and Static (Positive) groups for Grade 11 participants, with participants in the Static (Positive) group obtaining higher post-test scores *(M = 4.17).* There was also a significant difference in post-test scores for Grade 11 participants in the Static (Positive) group and Static (Neutral) group. Participants in the Static (Positive) group had higher mean scores than participants in the Static (Neutral) group *(M = 3.31)*

Discussion

Participants who received the multimedia learning material, imbedded with positive graphics (in this case with anthropomorphised characters), performed better in terms of comprehension, than participants who received the same material when the graphics were not given a human-like form. This improvement was evident when the learning material was in an animated format and when it was in a static format. Participants who received the positive static version with the anthropomorphised characters performed better than the neutral static group and better than the neutral animated group. The results have also shown that the participants with animated learning material did not necessarily perform better than participants who learned from the static material. The school environment did not affect the

participants' post-test scores, but their level of schooling did have an effect. Participants in Grade 11 performed better than participants in Grade 10, but only those who received the positive animation learning material when compared to Grade 10 participants who received the same material.

Participants who received the learning material in a positive animated format scored better on comprehension than participants who received the material in a neutral animated format. The positive static format also produced better results than the static neutral and even the animated neutral format.

The positive graphics in both the animation version and in the static version produced better results than their neutral versions, but only when the positive animation was compared to the neutral animation and the positive static as compared to the neutral static and the neutral animation. Plass et al. (2014) had already successfully established the effect of colour and shape, therefore, in our experiment, we explored a combination of design elements such as comic-like animated characters and added some humour to the characters as a strategy to engage the learners and create an emotional connection. Although our instruction is not equivalent to the one that Plass et al. (2014) used in their study, the general application of the design effects in the context of emotion is the same.

Implications of the current study

The studies of Schneider et al. (2016), Mayer and Estrella (2014), Plass et al. (2014) and Um et al. (2012), indicate that positive emotions through an induction process or using positive emotional graphics can facilitate learning. Their work suggests that positive emotions must be viewed as an essential variable that ought to be integrated into instructional design, particularly in multimedia learning situations. The results of this study support the tendency that decorative material, or positive graphics, may play a role in facilitating the learning process. However, the difference between this study and the work by Um et al. (2012) and Plass et al. (2014) is that this study did not use a positive mood-induction process in association with positive graphics. Our experiment also places more emphasis on the aesthetic value of the graphics in the learning material.

Several questions remain, at least from a graphic designer's perspective. Is it possible for decorative elements that aim to induce positive emotions, to improve learning without a positive mood-induction process? Learners normally engage with learning material on their own and do not have the advantage of a facilitator to induce a positive mindset before or during the learning process. Given that there is consensus by earlier scholars that decorative graphic elements do not facilitate learning, we question whether positive graphics, in the absence of a mood-induction process and despite our own positive results, would have the ability to improve learning. In our view, when learners experience positive emotions (which can be induced through positive decorative visual graphics), it can stimulate intrinsic motivation or the aspiration to learn without the introduction of external mood-induction procedure.

Limitations and future considerations

Designing and developing quality animations for teaching and learning can be challenging. Plass et al. (2014) have indicated that there is currently little theory-based, empirically validated guidance for determining how specific visual design elements (for example, shape) influence learners' emotions and foster learning. Studies from the perspective of graphic designers or illustrators could add value to this field of study. The experiment was conducted in a computer laboratory environment. One cannot only accept the results of a classroom

experiment and transfer this to a learning situation where learners are not limited as in the experiment. Future studies could be conducted in a classroom setting or in a more structured programme of learning to better explore the effect of different decorative graphics.

This article illustrates how we, as graphic designers could use the research methods traditionally used by the social and natural sciences.

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Terms and their meaning in the context of this paper

Aesthetic: Pictures that a viewer experience as pleasing to the eye. A subjective judgment.

Emotional graphics: Decorative elements such as a smiling face, or colour added to a graphic that is used in learning material. This term is somewhat confusing, as an image with a smiling face and in colour will not necessarily evoke an emotion. These are words and terms used by no-design scholars (see the work by Plass et al. 2014).

Decorative: Seductive decorative pictures consist of irrelevant but interesting learning material, while conducive decorative pictures may increase learning through mediating factors like positive emotions or interest (*see Schneider et al. 2016. Conducive pictures are similar to emotional graphics/pictures).

Representational and explanative pictures: Pictures that represent a concrete idea, such as an apple. An explanative picture would explain a process, for example, how the human heart works (see Anglin 1987, and Levie & Lentz 1982).

Anthropomorphic pictures: These are images that are given human-like characters. A good example is Walt Disney's Donald Duck.

Static images: Any of the above items, but in motionless format.

Animated images: Also referred to as dynamic images. The opposite of static, an image of a motion graphics project.

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