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Six Bottom-Up Visual Modulating Areas Are Valued by Observers After Having Viewed the Dalinian Image 'The Invisible Man': A Study Based on Ocular Fixations Analyses.

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Abstract
Salvador Dalí painted several paintings in which there were ambiguous images. Also known as bistable images, paintings like 'The invisible man' have the characteristic of having two or more possible perceptions. That is to say that different visual percepts can be perceived while observing this image. In order to observe if six different constituent parts of the 'invisible man' have the same level of salience, 69 participants took part in an experiment in which they observed the mentioned dalinian bistable image in front of an eye-tracker device (60Hz.). Eye-movements recordings were analyzed to stablish the durations of ocular fixations made on the six areas that were chosen following the criterium of having the capability of operate as bottom-up perceptual modulating factors. The results show that ocular fixations have a different duration when comparing gazes made on each area. Eyes and hair parts were the more observed ones. It was concluded that there are areas that are more salient when looking at the bistable image in question. This fact can vindicate that constituent aspects of visual stimulus have an influence on the perception of the image itself.
Key-words: *Ambiguous images; Bistable perception; Artistic images; Visual perception*

INTRODUCTION

It is a well-known fact that when an observer looks at an ambiguous visual figure that affords two possible interpretations, he/she may perceive each of the interpretations initially, and then, they can perceive the other one a short while thereafter (Hsiao et al., 2012; Leopold & Logothetis, 1999; Pisarchik et al., 2015). This phenomenon, that is called bistable perception, has been useful to look into human visual consciousness (Rodríguez-Martínez & Castillo-Parra, 2018). Several artists have painted paintings and images using ambiguous figures in order to create a particular sensation when looking at them (Filevich et al., 2017). It has been also stated that perception of bistable figures depends on the place of the figure where the observer makes ocular fixations (Marroquín-Ciendúa et al., 2020). On the other hand, this sort of perception is also related to semantic information that can influence the perceptual configuration. This influence, provided by external information in relation to the stimulus itself, is known as top-down perceptual modulating process (Wang et al., 2013; Weilnhammer et al., 2021). In this regard, paintings that were created using bistable images could be interpreted due to the meaning of their title, or also depending on the fact that the observer can listen or read instructions or information that influence his/her final perception (Rodríguez-Martínez & Castillo-Parra, 2018). As far as bistable paintings are concerned, it is a well-known fact that Salvador Dalí painted several images based on the principles of bistable perception. The influence of the Renaissance masters that Dalí saw in the great art galleries of Florence and Rome is clearly evident in the group of images he subsequently used in his paintings in order to establish multiple ambiguous images, as can be seen in paintings like Spain, The invention of the monsters, or also in The three ages (Martinez-Conde et al., 2015). In addition to this, the Catalan painter was extremely meticulous when he designed his 'invisible objects', regardless of the chosen theme. Thus, paintings such as Slave market with the disappearing bust of Voltaire, or The image disappears, epitomize the ideal of dalinian ambiguous figures, providing several interpretations to them (Hamer, 2024).

For its part, it has been established that areas of a bistable stimulus are fixated by the eyes during its observation (Marroquín-Ciendúa et al., 2020). These areas have the likelihood of exerting a perceptual modulating effect, which has been defined as a bottom-up perceptual modulating process (Hsiao et al., 2012; Rodríguez-Martínez et al., 2021). This way, modulating bistable perception involves interposing a condition or factor that influences or directs the observer's interpretation of the ambiguous visual stimulus (Rock et al., 1994; Rodríguez-Martínez & Castillo-Parra, 2018). Bottom-up modulating factors are understood as both physical characteristics of visual stimuli (García-Pérez, 1989; Borisyuk et al., 2009; Kornmeier & Bach, 2005), and critical areas of attentional modulation (Gale & Findlay, 1983; Rodríguez-Martínez et al., 2021). In this sense, constituent aspects of visual stimulus such as edges, angles, line thicknesses and textures, contribute with regard to a direction of their final perception (Biederman & Ju, 1988), as well as the areas and points in which ocular fixations are made (Meng & Tong, 2004).

It should be clarified that, apart from the physical characteristics of the stimulus, such as edges, protruding elements, shared contours, among others, the way in which the observer sees a bistable image also affects the interpretation of the stimulus (Marroquín-Ciendúa et al., 2020; Rodríguez-Martínez, 2024). To put it another way, certain areas and constituent aspects of a bistable image, lead to perceive a certain visual percept. When an observer fixes his gaze on said areas and characteristics, the recognition of the perceptum emerges (Gale & Findlay, 1983; García-Pérez, 1989; Rodríguez-Martínez, 2024). This type of perceptual modulation is understood, as already noted, as a bottom–up factor, because the characteristic (or modulating factor) involves sensory processing without information being provided that may imply a priming effect (Meng & Tong, 2004; Rodríguez-Martínez & Castillo-Parra, 2018).
For its part, the areas of ocular fixation vary during the observation of a bistable image, and there is a greater probability that the alternations (perceptual reversals) will occur if the image has more exposure time in front of the observer (García-Pérez, 1989; Hsiao et al., 2012; Pressnitzer et al., 2006). The reasons why the alternations occur have been explored to the point of wanting to determine if it is due to binocular rivalry that the phenomenon manifests itself, or if it is more due to the contrasts of the stimulus, or by the adaptation between the presence and absence of light, which is passed from one perceptum to another (García-Pérez, 1989). Eye movements seem to be the most likely cause of the alternations, but the records of eye movements made in some studies on bistable perception have not consistently revealed that a change in fixation follows or precedes an alternation (see Gale & Findlay, 1983). On the other hand, the fact that reversals can also occur voluntarily (Long & Topino, 2004), adds an additional issue, because it clearly indicates that both processes are involved, those of a top-down and bottom-up kind (Intaité et al., 2013; Kornmeier et al., 2009). Besides, it has been stated that memory priming effects that emerge while perceiving ambiguous images are related to top-down modulating perceptual processes, because what is stored in memory exerts an influence on what is visually perceived (Goolkasian & Woodberry, 2010; Rodríguez-Martínez et al., 2022).
Another factor that is involved is the distance between the observer and the recording device of ocular fixations (Funke et al., 2016). The visual field is defined by the limits that are established by both the vertical and the horizontal horopter (Arango et al., 2020). In turn, these horopters are the basis of the so-called 'Panum fusional area', which is the visual field itself divided in ranges of angles (Niechwiej-Szwedo et al., 2023). As can be seen in figure 1, within the Panum zone there are areas defined by angles, where the point in which ocular fixations are made ranges from -2^0 to 2^0 (Arango et al., 2020). In order to capture data concerning gazes and ocular fixations, it is necessary to place the observer at an approximate distance of 60-80 cm. (Wang & Cho, 2022). This way, the observer has the capability of observing the area of a regular monitor of an eye-tracker device on which visual stimuli are displayed (Vehlen et al., 2021). The images that are going to be viewed have to, ideally, fall within the Panum area (Miladinović et al., 2024).

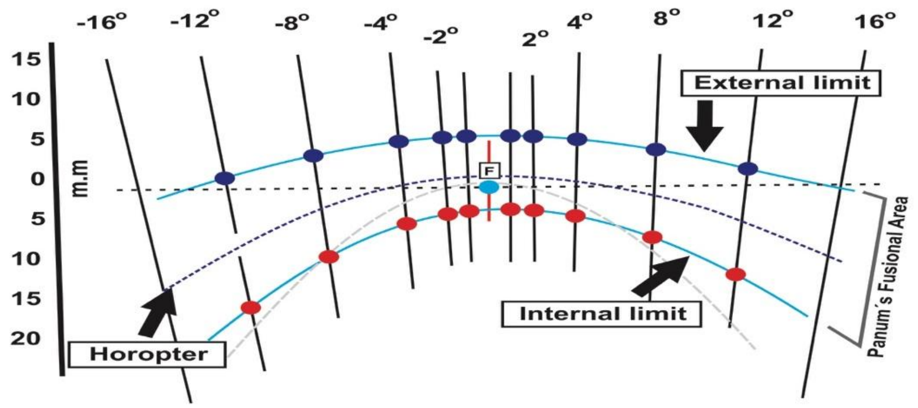

Figure 1. Panum's fusional area and its internal and external limits. The focus area is marked with letter 'F', just in the center of the horizontal horopter. Source: Adapted from Arango et al., 2020).

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To carry out research on the relation between observed fixation areas of a bistable image and the configuration of visual percepts, it is necessary to have control over the recording of oculo-motor activity, trying to determine which percept is configured in relation to pre-determined areas of the bistable stimulus (Chastain & Burnham, 1975; Gale & Findlay, 1983; Hsiao et al., 2012; Rodríguez-Martínez et al., 2021). In the same way, the manipulation that is done in relation to directing attention to one or another area of the bistable image might have a relevant impact on what is perceived by the observer, also allowing to infer that the first glance determines the perception of the ambiguous stimulus, if the observed area conditions (or favors) one of the possible perceptions of the bistable stimulus (Chastain & Burnham, 1975; Gale & Findlay, 1983; Hsiao et al., 2012).

As far as the ambiguous images painted by Salvador Dali are concerned, several studies have been conducted in order to establish certain principles, visual rules, and graphic statements concerning lines and strokes that are involved in both the conception and perception of hidden images inside the paintings themselves (e.g. Finkelstein, 1983; Hinterwaldner, 2013; Marković, 2011; Wade, 2021), In this regard, several areas have been recognized as zones that can exert bottom-up perceptual influences while viewing ambiguous dalinian images (Finkelstein, 1983). As such, and following the statements given by Finkelstein (1983) in relation to the disambiguation of images hidden in the painting Sleeping woman-horse-lion, six areas can be considered as salient in relation to the recognition of the depicted man: zones concerning hair, eyes, shoulders and hands, are useful to recognize the shape of the invisible man. As Atay and De la Roca (2019) stated, there is a figure-ground illusion while viewing images like The invisible man (see it in figure 2), where some physical clues contribute to perceive the images that remains hidden as if there is a kind of camouflage ready to be discovered (Elias, 2012). As a matter of fact, several perceptual rules, such as the Gestalt Principle of Closure is present in The invisible man, because the figure seems to be incomplete (Martínez-Conde et al., 2015), but our perceptual system restructure the visual signals so as to configure an understandable percept (Rodríguez, 2016). A figure-ground perceptual shift also emerges because some independent figures constitutes other ones while mentally reorganizing new visual gestalts (Gori et al., 2008; Kogo et al., 2015). A great deal of our daily experience implies feats like this (Martínez-Conde et al., 2015), where it is necessary both to fill perceptual gaps and reinterpret the visual stimulus to reach a disambiguation of it (Qiu et al., 2009).

Figure 2. The painting 'The invisible man' placed in a grid that has been designed so as to identify bottom-up modulating areas corresponding to the recognition of the man depicted. Source: Own design.

In order to clarify what the six areas mentioned before concerning The invisible man image are, in figure 3 (section 'method', below) these six zones have been highlighted in relation to the constituent parts of the man depicted. The grid that was used to choose the six areas of interest (AOIs) was designed in line with the proposals given by Bernal (2020). The purpose of the study outlined here was trying to establish the best valued area in terms of its importance to recognize the hidden figure in the painting The invisible man. The study was also aimed at identifying the most salient visual areas based on the durations of the ocular fixations made on the six ones selected as AOIs.

METHOD

69 participants took part in an experiment (mean of age, M=26,782; S.D.= 5,005; women, 52,17%; men, 47,82%). They observed the dalinian bistable image The invisible man, in front of an eye-tracker device (60 Hz.). The image was displayed for 10 seconds. After the calibration phase, each participant read the instructions on the monitor. They said that an image was going to be presented. After that sentence, an instruction emerged, saying 'try to find the face of a man, his shoulders and his hands'. Once all the data was collated, the previously mentioned six areas of interest (AOIs) were marked, intending to establish their relation to the visual percepts that were wanted to be recognized. After that, a data base was arranged so as to state the durations of ocular fixations made on these six areas. As the data was arranged that way, the Kolmogorov-Smirnov statistical test was done in order to determine the normality of the data in question. In accordance with the results, it would be necessary to stablish if what was needed to measure the hypothesis would be parametric or non-parametric statistical analyses. It was hypothesized that there would be differences between the ocular fixations made on the AOIs, according to what Bernal (2020) and Rodríguez-Martínez (2024) had stated in terms of determining bottom-up areas more salient than others, using square grids to give AOIs the same area. Once the participants finished their visual task, they filled in a questionnaire in which there were Likert scales (from 1 to 5), concerning the assessment given to each AOIs in terms of their importance in relation to identify the invisible man of the painting. It was hypothesized that the area referring to the eyes of the invisible man would be the best valued area, due to the importance that eyes have to identify human faces (Hammerschmidt et al., 2017). The other hypothesis was that hands would be more relevant to identify the invisible man in relation to the shoulders. The six AOIs selected are shown in figure 3, as mentioned before.

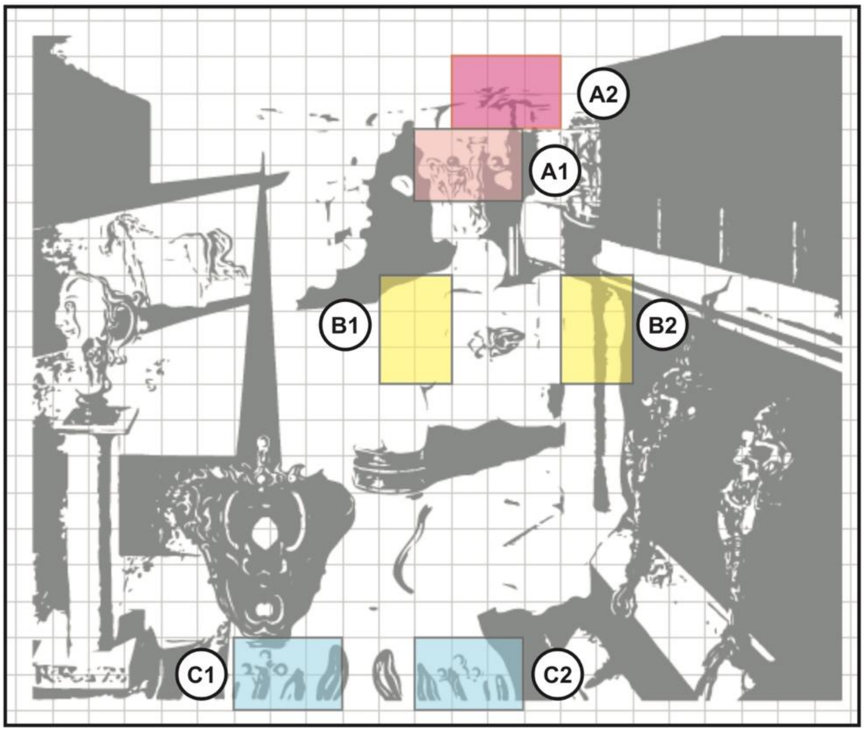

Figure 3. The six AOIs selected. A1 is the area concerning the eyes of the invisible man. A2 refers to his hair. B1 and B2 involves the shoulders of the figure. C1 and C2 are, respectively, the left and the right hand (from the point of view of the observer). Source: Own design.

RESULTS

The Kolmogorov-Smirnov test showed that the data had no normal distribution, but for the AOIs 'Right shoulder', as can be seen in table 1:

Table 1. Kolmogorov-Smirnov test results

AOIs	Kolmogorov-Smirnov statistical value	gl.	Sig.
A1 - Eyes	0,163	69	<0,001
A2 - Hair	0,247	69	<0,001
B1 - Left shoulder	0,152	69	<0,001
B2 - Right shoulder	0,101	69	<0,080
C1 - Left hand	0,152	69	<0,001
C2 - Right hand	0,162	69	<0,001

Given the fact that the data concerning durations of ocular fixations in the AOIs had no normal distribution, it was necessary to carry out non-parametric statistical tests. As such, and considering the fact that there were multiple measures for each participant (six performances observed, each of them concerning each AOIs), it was necessary to do the Friedman statistical test. With a K value equal to 6 (K =6), once the test was done, a p value that implied statistical significance was found (Friedman's statistical value =220,479; N =69; gl =5; p =0,000). When considering the durations of ocular fixations, there are differences among the six AOIs, as can be seen in table 2:

Table 2. Comparisons among durations of ocular fixations

AOIs	Mean (time of ocular fixations)	Standard deviation	Median
A1 - Eyes	1,94	0,054	1,83
A2 - Hair	1,53	0,048	1,45
B1 - Left shoulder	0,68	0,062	0,73
B2 - Right shoulder	1,07	0,051	1,05
C1 - Left hand	0,76	0,056	0,87
C2 - Right hand	0,78	0,055	0,88

As far as the comparisons made between each sample and the others, 12 significant differences were found, out of 15, as shown in table 3. There was no statistical significance when comparing the following pairs of samples: B1–B2, B1–C1, and C2–C1.

Table 3. Comparisons between durations of ocular fixations

Samples compared	Statistical value	Mean values compared	Standard error	Statistical standard test	Sig.
B1 – B2	-0,123	0,68 – 1,07	0,319	-0,387	0,699
B1 – C1	-0,174	0,68 – 0,76	0,319	-0,546	0,585
B1 – C2	-1,225	0,68 – 0,78	0,319	-3,845	<0,001
B1 – A2	2,449	0,68 – 1,53	0,319	7,690	<0,001
B1 – A1	3,638	0,68 – 1,94	0,319	11,421	0,000
C2 – C1	0,051	0,78 – 0,76	0,319	0,159	0,873
C2 – B2	1,101	0,78 – 1,07	0,319	3,458	<0,001
C2 – A2	2,326	0,78 – 1,53	0,319	7,303	<0,001
C2 – A1	3,514	0,78 – 1,94	0,319	11,034	0,000
C1 – B2	1,051	0,76 – 1,07	0,319	3,299	<0,001
C1 – A2	2,275	0,76 – 1,53	0,319	7,144	<0,001
C1 – A1	3,464	0,76 – 1,94	0,319	10,875	0,000

B2 – A2	1,225	1,07 – 1,53	0,319	3,845	<0,001
B2 – A1	2,413	1,07 – 1,94	0,319	7,576	<0,001
A2 – A1	1,188	1,53 – 1,94	0,319	3,731	<0,001

As for the assessments given by the participants to each AOIs in relation to their importance to recognize the invisible man, there are areas that are better assessed than others, as can be seen in table 4, where area A1 (eyes) is the best assessed, and area B1 (left shoulder), the worst.

Table 4. Assessment given by the participants to the selected areas

AOIs	Score (mean)	Standard deviation
A1 - Eyes	4,52	0,073
A2 - Hair	2,82	0,111
B1 - Left shoulder	1,89	0,09
B2 - Right shoulder	2,94	0,092
C1 - Left hand	3,53	0,078
C2 - Right hand	4,1	0,077

One thing is what the observers think about the relevance of each area, and a different one is the performance of ocular fixations made on them. A statistical test concerning correlations (Spearman test), was carried out in order to find out if some significant relation could be found between the time of ocular fixations made on each area and the score given to them by the participants. In table 5, the results of the analyses are shown:

Table 5. Correlation values between durations of ocular fixations and scores given by participants concerning the AOIs

AOIs and Scores	Rho of Spearman	Sig.
A1 - Eyes	-0,222	0,67
A2 - Hair	0,72	0,554
B1 - Left shoulder	0,101	0,41
B2 - Right shoulder	0,61	0,616
C1 - Left hand	-0,126	0,302
C2 - Right hand	-0,086	0,481

DISCUSSION

The fact that several significant statistical differences have been found in terms of durations of ocular fixations made on the 6 AOIs, gives an account of the difference that exists in terms of attentional salience in relation to bottom-up modulating areas. It is not surprising that the area concerning the eyes of the invisible man had the better performance in terms of having been viewed because it has been stated that eyes are one of the most salient visual features of human faces (Hammerschmidt et al., 2017). As a matter of fact, all the pair-comparisons made in relation to area A1 (eyes) have statistical significance, which means that this area is relevant in terms of being an attentional modulating factor. It was also found that, when comparing left and right shoulders, there is no a significant statistical difference in favor of one of them, leaving shoulders, statistically speaking, at the same level of salience. The same happens to the hands: while viewing the p value, there is no statistical difference when comparing the durations of ocular fixations made on them. Nevertheless, when reviewing the results comparing different parts of the body (hair and eyes, hands and eyes, hands and shoulders), differences arise between left hand and right shoulder (in favor of the shoulder), and also between left shoulder and right hand (in favor of the right hand). Besides, all the comparisons made in relation to area A2 (hair) have significant statistical differences in favor of that area when drawing parallels with both shoulders, and also with both hands. The fact that there are more salient areas when viewing a bistable image after having been instructed about finding the features in question (hair, eyes, hands, and shoulders), can vindicate the claim that constituent aspects of visual stimulus such as edges, angles, line thicknesses, etc., contribute to drive their final perception (Biederman & Ju, 1988; Marroquín-Ciendúa et al., 2020). As has been stated, certain areas and constituent aspects of a bistable image can lead to perceive a specific visual object that is a part of an image. In this regard, if observers fix their gazes on bottom-up modulating areas, the recognition of the certain percepts arises (Gale & Findlay, 1983; García-Pérez, 1989; Rodríguez-Martínez, 2024).

It has to be considered that, given the fact that there was an instruction in relation to finding the face of a man, his shoulders and his hands, the observation of the dalinian bistable image was influenced in a top-down way (Hartcher-O'Brien et al., 2017; Katsuki & Constantinidis, 2014; Kiefer, 2007). As stated by Barrera and Calderón (2013), top-down processes involved the presence of pieces of information that can condition attentional and perceptual processes. In addition to this, the perception of a bistable image as a whole is complicated to be understood, due to the fact that, while viewing an ambiguous image, perceptual reversals emerge, sometimes because of pure attentional factors, and sometimes owing to top-down modulating factors (Leopold & Logothetis, 1999; Rodríguez, 2023; Sterzer & Rees, 2009). Nonetheless, what has to be pointed out is the fact that there were AOIs more viewed, where eyes and hair were the more salient features of the image observed. Once again, it has to be mentioned that faces are rather salient when looking at humans (Hammerschmidt et al., 2017; Liu et al., 2017). In this spirit, a fact that emerges here in that hair is a part of the human head. In order to visually identity human faces, the recognition of the head as a whole is a factor that is involved (Bruce et al., 1991), as well as the visual identification of eyes (Walker-Smith et al., 2013). Accordingly, it can be understood why the results show that both, hair and eyes, are the most prominent features visually speaking.

When considering the assessments given by the participants in relation to the importance that AOIs have to recognize the invisible man, it is interesting that the best valued areas were eyes (A1 area) and hair (A2 area). However, according to the correlational statistical analyses, there were no significant correlations between the scores and the durations of ocular fixations (as shown in table 5). Regardless of the fact that there were no significant correlations, descriptively speaking, it is notable that the two best scored areas were eyes and hair. Future research projects will have to be conducted so as to carry on understanding the role that visual features play when perceiving bistable images that are constituted by separate forms, just as happens with the 'Invisible man' painted by Salvador Dalí.

CONCLUSIONS

Ocular fixations have a different duration when comparing gazes made on six relevant bottom-up modulating areas of the image The invisible man painted by Salvador Dalí. The area concerning the eyes is the one that has the better performance in relation to durations of ocular fixations made on it. There are more salient areas when looking at the bistable image in question, which might vindicate the claim that constituent aspects of visual stimulus exert an influence on the way the image is perceived. There are AOIs more viewed, whereby eyes and hair are the most salient features of the dalinian bistable image used. As far as the assessments given to the importance of the six areas in question are concerned, the best valued areas are eyes and hair, but with no significant correlations between the scores and the durations of ocular fixations made on the areas themselves. Seemingly, visual features play a role when perceiving bistable images that have several parts that constitute them, like the surrealist image analyzed in the present study.

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