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Can ocular fixations modulate the perception of a bistable logo? An eye-tracking study

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Abstract
Bistable logos accept two different interpretations, where each interpretation can be conditioned by the area of the image that is being observed. Thus, ocular fixations can affect their final perception. To determine if the eye fixation areas influence the perception, 20 volunteers observed a bistable logo in front of a fixed eye-tracker, reference Tobii T-120. The results indicate that the reported percepts are related to ocular fixation areas. It is concluded that there are areas that affect the identification of the possible percepts of the bistable logo, which leads to essential considerations for graphic designers to optimize graphic brand communication.

Keywords
Brand communication; bistable logos; eye-tracking; bistable perception; eye-fixations

¿Pueden las fijaciones oculares modular la percepción de un logotipo biestable? Un estudio basado en registro de movimientos oculares

Resumen
Los logotipos biestables aceptan dos interpretaciones que pueden estar condicionadas por el área que esté siendo observada. Así, las fijaciones oculares pueden afectar la percepción final. Para determinar si las zonas de fijación ocular influyen en la percepción, 20 voluntarios observaron un logotipo biestable frente a un eye-tracker fijo (Tobii T-120). Los resultados indican que las percepciones reportadas están relacionadas con las áreas de fijación ocular. Se concluye que existen áreas que inciden en la identificación de las posibles percepciones del logotipo biestable, lo cual deriva en implicaciones para los diseñadores gráficos de cara a optimizar la comunicación gráfica de marca.

Palabras clave
Comunicación de marca; logotipos biestables; registro de movimiento ocular; percepción biestable; fijaciones oculares

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Introduction

Eye-tracking techniques and their usefulness in graphic design

Oculomotor activity recording techniques allow monitoring and observing eye movements while looking at a certain object (Rosa, 2015). These techniques, also known as *eye-tracking techniques*, seek to understand how an observer analyzes and looks at a given stimulus or set of visual stimuli, being able to take several measurements to make analysis and find answers to a particular question regarding oculomotor activity (Chamberlain, 2007). In this sense, it is possible to determine eye fixation patterns, fixation durations (in millisecond units that will be higher or lower depending on the specific *eye-tracker* device), displacements and vectors of saccadic movements, coordinates of each eye fixation, pupillary diameter change activity, among others (Tien et al., 2014).

Given that through *eye-tracking* techniques it is possible to define areas of interest to be analyzed with research criteria, comparison of hypotheses, or just to describe perceptual phenomena, advertising agencies and graphic designers use this instrument to define which parts of an ad or of a logo are mostly detected (e.g. Park et al., 2020; Rosenlacher and Tichý, 2021). In this way, it is studied how attentional patterns correlate (or not) with cognitive measures associated with the understanding and recall of the message (e.g. Krugman et al., 1994; Scott et al., 2016), and how the decoding of graphic designs can elicit emotions (e.g. Zamani et al., 2016), and also a preference for brands and products displayed on a screen (e.g. Guo et al., 2016). With this regard, the effectiveness of ads and brands has found in this type of instrument a useful alternative to determine reading patterns manifested in the observation of visual stimuli (e.g. Scott et al., 2016). These patterns are checked in relation to responses and attitudes of consumers (Motoki, Saito, and Onuma, 2021).

Ocular fixations and their role as modulators of perception

In the field of visual perception research, there is a particular domain that accounts for how humans perceive visual stimuli that, while remaining invariant, admit two different possibilities of interpretation: bistable perception (Weilnhammer et al, 2021). Visual stimuli that accept two different possibilities of interpretation are called bistable or ambiguous images (Pisarchik et al., 2015). The alternation that occurs when switching from one percept to another is called *perceptual reversal* (Brancucci et al., 2020). Several studies focusing on bistable perception have demonstrated the implications of *bottom-up* and *top-down* perceptual processing (Kornmeier and Bach, 2012). Bottom-up perceptual mechanisms involve sensory-perceptual processes where the configuration of the visual percept involves the passage of information from the retina to areas in the visual cortex (Fan et al., 2020). On the other hand, top-down perceptual processing involves modulations of perception according to information that is exogenous to the perceived stimulus.

Bringing back to bottom-up mechanisms, physical aspects of bistable visual stimuli, such as edges, lines, angles, and textures, among others, contribute to their final perception, as well as ocular fixation points do (Hsiao et al., 2012; Marroquín-Ciendúa et al., 2020). Thus, these elements can be understood as bottom-up modulators (Awh et al., 2012). Hsiao et al. (2012) point out that ocular fixation points operate as bottom-up modulators, because the characteristics of the physical stimulus guide observer's attention and, subsequently, influence their perception, without the mediation of information stored in memory that would lead to assume the presence of top-down mechanisms (Motoki et al., 2021). Given that eye fixation areas have been shown to influence perception (e.g., Gale and Findlay, 1983; Hsiao et al., 2012), when designing bistable images, the designer should estimate that the two possible percepts may or may not have a similar probability of being interpreted, depending on the areas through which they are observed (Peters et al., 2005).

Regarding the study of the incidence of specific areas of ocular fixation on the perception of bistable images, studies conducted with eye-tracking techniques stand out (e.g. Gale and Findlay, 1983, Hahn et al., 2006, Hsiao et al., 2012, Marroquín-Ciendúa et al., 2020, and Sato et al., 2020). In essence, from the review of these studies, it is evident that there are critical areas of ocular fixation that favor a certain perceptual configuration for visual bistable stimuli. That is the case with the Boring's bistable image *my gilrlfriend or my mother-in-law* (see it in Boring, 1930). According to Gale and Findlay (1983), it was established that specific areas of ocular fixation allowed the participants to recognize the young woman percept, whereas there were other areas of the image that favored the old woman percept (see figure 1). These findings were ratified by Marroquín-Ciendúa et al. (2020), where the critical areas of modulation suggested in the previous study were observed. As a matter of fact, certain areas of ocular fixation are associated with the interpretation of a particular percept of a bistable image. In figure 1, it can be seen, on the right, the four defined areas:

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A1 modulates the perception of the young woman, while area A3 influences the old woman percept. Areas A2 and A4 favor indistinctly the two possible percepts. On the left, specific modulation points have been marked: (a) is a point that modulates the old woman percept and (c) is a fixation point that favors the young woman percept; (b) is assumed to be a neutral fixation point.

After having experimentally identified modulating fixation points, Hsiao et al. (2012) concluded that what an observer perceives is highly conditioned by fixation points that are presented prior to the observation of the bistable stimulus. The way observers see logotypes has also been studied by using eye-tracking techniques (e.g. Girisken and Bulut, 2014; Park et al., 2020; Rosenlacher and Tichý, 2021), a fact that lead us to state that research based on the psychology of visual perception may have an applicability in graphic design of brands and logotypes.

The study outlined here was aimed at determining whether eye fixations on critical bottom-up modulation areas of a bistable logo affect the configuration of the percept that is favored by gazing at these areas. It was hypothesized that the percept reported at the end of the exposure of the bistable logo would correspond to longer durations of eye fixations in the modulating areas with respect to the times of fixations manifested in unrelated areas to the identified percept. In other words, we wanted to establish the modulatory effect of eye fixations on the interpretation of a bistable logotype, assuming that the longer a modulatory area is viewed, the greater the probability that the percept identified is the one related to that area. For the purpose of determining the visual percept, the so-called *percept prevalence paradigm* was taken into consideration, whereby, regardless of the occurrence of perceptual reversals, a prevalent or dominant percept is recognized, based on subjective reports or objective measures (e.g. Knapen et al., 2011; Wang et al., 2013).

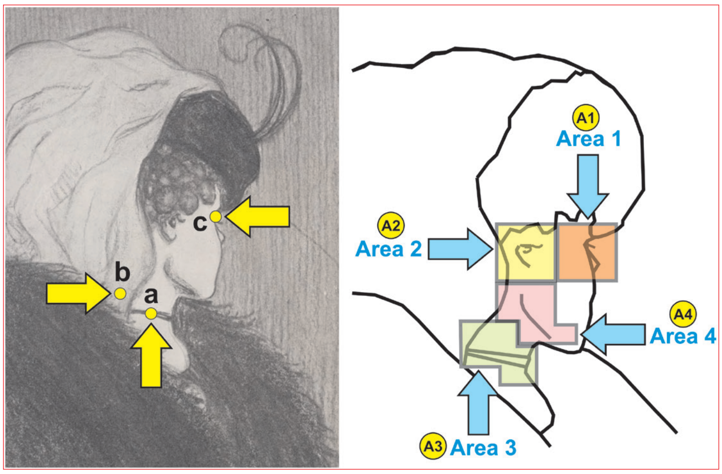

Figure 1. Areas of ocular fixation that favor the perceptual configuration of the bistable image. Source: adapted from Gale and Findlay (1983), and Hsiao et al., (2012).

Method

Design

A visual task was designed consisting of observing the SPARTAN GOLF CLUB® logo for thirty seconds in front of a fixed 120 Hz. eye-tracker, Tobii® technology, reference T-120. A simplified version of the logo (line drawing) was used, following the procedure used by Gale and Findlay (1983), by which textures, gradations and colored areas are eliminated (see it in figure 2). The image was simplified in order to minimize external visual inputs that could modulate attentional processes concerning the observation of the image itself. Using an experimental design, the aim of this study was to establish whether there was a relationship between the ocular fixations made in certain modulation areas and the visual percept identified (a golfer or a Roman soldier's head). It was hypothesized that the durations of eye fixations recorded would be longer in the critical areas of modulation that favor the reported percept than in the areas that do not modulate it.

Participants

From a total of 23 tests performed (23 participants), 20 were selected, under the criterion of establishing an equal number of recognitions for each of the two possible percepts when observing the bistable logo. Given that there were 13 participants who reported one visual percept versus 10 who reported the other one, 3 of those who recognized the first percept were randomly eliminated, leaving, this way, the two groups equal with 10 participants. The description of the total of 20 participants finally selected according to the previously stated criteria is as follows: 50% male, 50% female; age range between 19 and 26 years; M = 22.35; SD = 1.78. All of them were unaware of the purpose of the study and had normal or corrected vision (wearing contact lens). Each of them provided written informed consent. The visual task was performed in an experimental laboratory of psychology.

Procedure

Instructions were given to the participants to perform the test inside the experimental laboratory of psychology. There, each participant observed the bistable logo for 30 seconds, in front of the

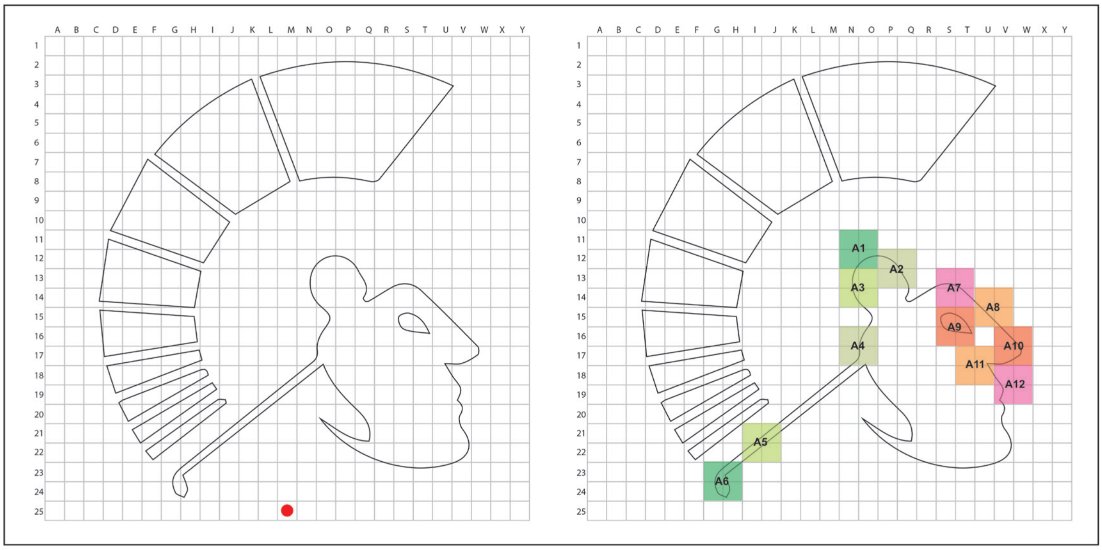

Figure 2. The bistable logotype used in the experimental test. On the left, and below (in the center), the placement of the initial ocular fixation point is shown (in red). That point was used so as to control the first ocular fixation of every single participant as Hsiao et al. (2012) suggested. On the left, the ocular fixation areas defined for the study are shown: A1, A2, A3, A4, A5 and A6 correspond to modulatory areas of percept G (golfer). Areas A7, A8, A9, A10, A11 and A12 are associated with percept C (Roman soldier's head or face). Source: own design.

eye-tracker device. The distance established between each participant and the monitor was 60 centimeters, as reported in other studies (e.g., Marroquín-Ciendúa et al., 2020). Each participant was instructed to keep their head still during the task. The participants had to report, at the end of the bistable stimulus exposure, the percept they identified (golfer or Roman soldier's head/face). Each participant was only allowed to report a single identified percept, giving a single response even if they had recognized different shapes during the observation, taking as reference a prevalent or dominant percept paradigm (e.g., Knapen et al., 2011; Wang et al., 2013). The dominant percept identified was obtained through a final question that led participants to determine the dominance between one of the two possible percepts. As such, the answer would be 'golfer', if the most recognized percept was a golfer (percept "G"); or 'Face', if the dominant visual percept was the face of a Roman soldier (percept "C"). The collected data was organized in a spreadsheet, discriminated by the durations of the eye fixations and by the observed areas, in relation to G and C percepts. 12 observation areas were considered in the study (see figure 2, on the right), 6 referring to the golfer percept (areas A1, A2, A3, A4, A5 and A6), and other 6 corresponding to areas influencing the recognition of the Roman soldier's face (A7, A8, A9, A10, A11 and A12). Each of these ocular fixation zones had the same area (in terms of square millimeters) and were defined in relation to a general grid, so that each of them constituted a square made up of only four quadratic units (see figure 2). The definition of these zones, in relation to their potential modulation, was given in accordance with the findings of the exploratory study carried out by Bernal (2020). To test the stated hypothesis, the durations of the ocular fixations that were made on the modulating areas corresponding to the reported percepts were collated. All data were processed using the programs Tobii Studio®, Excel® (v.16.45) and SPSS® (v.23).

Results

When reviewing the results obtained, from a purely descriptive point of view, it can be seen that the areas of ocular fixation that are related to the corresponding reported percept, either percept C or percept G, are mostly observed. Before performing an inferential statistical analysis, the durations in the modulation areas corresponding to the favored identification of C and G percepts were reviewed (see tables 1 and 2).

Statistical analyses were performed by comparing the times of eye fixations in the modulatory areas associated with each percept with the times of eye fixations made in the modulatory areas of the opposite percept to the one reported. Thus, if a participant reported having seen the 'golfer' percept, the time of eye fixations in the areas that

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	Area	A1	A2	A3	A4	A5	A6
G	Sum	57,25	48,1	48,89	59,19	31,36	18,36
	Average	2,862	2,405	2,444	2,959	1,568	0,918
	Variance	9,076	8,806	5,381	6,542	6,839	4,215
C	Sum	14,05	30,18	39,49	47,36	20	0
	Average	0,702	1,509	1,974	2,368	1	0
	Variance	0,786	3,091	4,867	7,006	3,351	0

Table 1. Durations of ocular fixations in the modulatory areas of percept G (A1, A2, A3, A4, A5, A6).[1]

1. The 'G' and 'C' values in the first column correspond to the reported percepts G and C, respectively. These durations are shown in relation to reported percepts G (percept congruent with modulatory areas, upper section), and C (percept not congruent with modulatory areas, section below).

	Area	A7	A8	A9	A10	A11	A12	B.G.
G	Sum	14,94	48,8	2,19	43,95	27,25	25,4	174,32
	Average	0,747	2,44	0,109	2,197	1,362	1,27	8,716
	Variance	1,75	5,5	0,071	8,6	3,95	4,48	70,731
C	Sum	59,51	73,32	2,19	65,41	45,07	33,42	170
	Average	2,975	3,666	0,109	3,27	2,253	1,671	8,5
	Variance	2,932	6,01	0,071	9,178	6,391	5,235	52,272

Table 2. Durations of ocular fixations in the modulatory areas of percept C (A7, A8, A9, A10, A11, A12).[1]

1. The values 'G' and 'C' in the first column correspond to the reported percept G and C, respectively. The convention 'B.G.' means 'background'. It alludes to eye fixations made in areas different from the 12 selected areas. These durations are presented relative to reported percepts C (percept congruent with modulatory areas, lower zone of the table), and G (percept not congruent with the modulatory areas, upper zone of the table).

favored that percept was compared with the time of eye fixations in the areas that did not favor that percept. The same was done for the 'Head' percept. Thus, a paired system of data was generated so that a comparison of means was made, first between the times of fixations in modulatory areas of percept C and the times in non-modulatory areas of that percept (see figure 3, on the left), and then between the times of fixations in modulatory areas of percept G and the times in non-modulatory areas of that percept (see Figure 4, on the right).

When considering the reports that corresponded to percept G where observations in the modulation areas of that percept were involved (see in table 1, upper section), it is found that the average durations of those eye fixations [(M = 13. 15; SD = 9.23); $t(19) = 1.729$; $p = .044$)] is significantly longer than the average durations of fixations when the same G-percept was reported to be associated with non-modulating areas (M = 8.12; SD = 5.33), as seen in table 2, on the top.

On the other hand, the reports referred to percept C in correspondence with the observation of its modulatory zones (see table 2, below), imply a significantly longer duration of eye fixations [(M = 13.946; SD = 5.61; $t(19) = 4.21$; $p < .001$)], than the time given when the same percept is reported (M = 7.554; SD = 4.2), but with eye fixations made on non-modulatory areas (see table 1, section below). Figure 3 illustrates the differences that exist between the reports of the two percepts that can be identified in the bistable logo exposed to the participants, where a difference in favor of the identification of each percept is recognized when there is a longer duration of eye fixations in the critical areas of perceptual bottom-up modulation.

Discussion

In accordance with the results, it is recognized that there is a modulatory effect on the perceptual configuration of the bistable logotype. These results are in line with the findings found in the study conducted by Marroquín-Ciendúa et al. (2020). However, in the study described in the present article, the modulation mechanism of bistable perception was tested, this time not on a bistable image traditionally

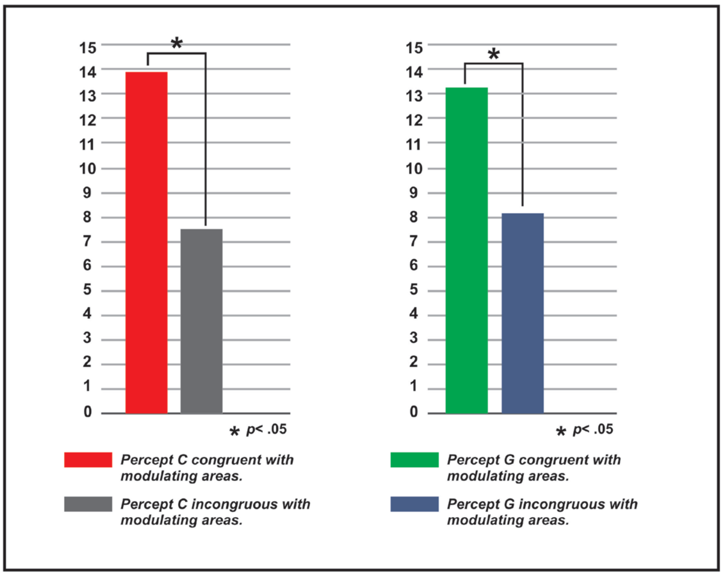

Figure 3. Comparison of the averages of eye fixation durations on congruent and incongruent modulation areas with each of the two reported percepts. Time units represented are seconds. Source: own design.

used in the context of psychological research (e.g., Rock et al., 1994; Kornmeier and Bach, 2012; Hsiao et al., 2012), but in relation to a brand that has the characteristics of bistable visual stimuli.

This application of the mechanisms involved in bistable perception is a valid contribution to be considered by those who design this type of visual stimuli in the context of brand communications. Specifically, the technique of recording oculomotor activity (eye-tracking), is claimed as a valid instrumental alternative to unravel perceptual mechanisms involved in the consumer/brand relationship, where, prospectively, it is visible how this instrumentalization could contribute to decisions related to design and communications, based on the knowledge and paradigms involved in matching measures of eye movement registration (Rosa, 2015). If brand designers decide to create a visual stimulus with a double semantic load in order to contribute to the realization of a certain strategic brand and/or marketing plan, and if they use visual brand identifiers of bistable nature to convey these two different meanings, the contributions of eye-tracking studies would help improve the design of logotypes. Likewise, if they manage to establish visual patterns so as to identify modulating areas that guide both the interpretation and decoding of the semantic loads involved, the design of the logo could have a better perceptual performance.

Reviewing the results of the present study, some relationships between certain specific areas of the image and their respective final perception can be observed. The attentional patterns involved are linked to the duration of each ocular fixation, a fact that leads to the idea that, at the level of brand design, there may be a preference or an attitude towards the visual stimulus, just as Ghosh and Bhatnagar (2013) point out.

It should be noted that the study documented here tested a single brand identifier, under the unfilled and uncolored stroke paradigm, previously used by Gale and Findlay (1983). To further unravel the mechanisms involved in the decoding of bistable brand identifiers new studies will have to be conducted, where attentional patterns and ocular fixations are also analyzed when the brands are exposed with their original colors and textures, and where other variables involved are collated, such as, for example, the brand slogan, which can contribute, due to its semantic load, to decode bistable logos on the basis of the functioning of top-down modulating mechanisms and the involvement of semantic congruency effects (Hartcher-O'Brien et al., 2017; Hsiao et al., 2012).

The present study is based on the fact that ocular fixations affect the detection of edges and features of the stimulus, a fact that has an impact on the visual processing of shapes (Biederman, and Ju, 1988). In addition, it takes as a reference that the emphasis placed on the strokes, lines and segments constituting bistable logos, may eventually favor a disambiguation of these ambiguous images, that is, to modulate one perception of the bistable image over the other. This fact supports what Gale and Findlay (1983) had mentioned in the sense that by emphasizing certain traces of the bistable stimulus it is possible to further favor the perceptual configuration of one of its possible percepts. However, it should be estimated that this modulated ocular fixation is momentary, and, then, the observer begins to make saccadic movements in various directions that can exert an influence of the perceived percept. This implies that attentional control is also temporary, and that, given that each observer can initiate his or her saccades indistinctly toward one or another location, the stochastic characteristic inherent to bistable perception emerges as a fact to be taken into account (Albert et al., 2017).

In this sense, some limitations should be considered: first, it was procedurally determined that each participant should choose a single percept, which means selecting just a single interpretation of the image. That implies that, although each participant could have recognized the two percepts during the observation, he/she was only allowed to choose the dominant percept between the two possible identifiable percepts of the bistable logo. Even though it makes it possible to establish a potential association between the chosen percept and the most observed areas of the image, this fact only allows defining this relationship in a global way, and not by detailing the analysis for each percept that the participants could identify during the whole observation process. In this spirit, another limitation emerges, in the sense that in this study perceptual reversals were not taken into consideration. In the light of all this, future research will have to be conducted with the purpose of analyzing the relationship between observed areas of the bistable logos and their possible percepts, capturing each identified percept with the corresponding perceptual reversals and ocular fixation times for each interpretation reported during the experimental task. Nevertheless, the obligation to select a single percept identified during the observation of the bistable logo contributes to the understanding of the phenomenon: when each participant gives more importance to one percept over another, a greater preponderance of that percept is recognized in some sense, a fact that may be associated with the duration of eye fixations in areas that favor its identification (Hsiao et al., 2012). In addition to the limitations pointed out here, it is important to suggest that future studies could include more participants, in order to obtain more significant results.

To close this section, it is worth mentioning that due to the recording of oculomotor activity, it is possible to study various attentional and perceptual phenomena that can explain consumer responses in relation to factors involving the decoding of messages and visual stimuli that are designed as part of advertising tactics (Rosa, 2015). The study described here shows how research instruments and paradigms used in the context of the psychology of visual perception, such as, for example, perceptual bistability, the mechanisms of modulation of perception, plus the recording of saccadic movements and eye fixations, have a direct application in the domain of brand communication, and also in the field of designing logos. This kind of research contributes to the understanding of the perceptual mechanisms by which observers can decode a certain visual brand. As a matter of fact, previous studies have shown the relevance of understanding eye-movements and eye-fixations within the scope of perceiving and decoding brands (e.g. Girisken and Bulut, 2014; Rosenlacher and Tichý, 2021). In this sense, as Park et al. (2020) pointed out, there are graphic factors that exert an influence on both, attention and perception, while observing logotypes. Regarding bistable visual stimuli, it has been stated the importance of physical features of bistable images in relation to their perception (Weilnhammer et al., 2021). By considering the results shown in the present study, graphic designers could incorporate tests based on eye-tracking techniques, so that bistable logotypes designed by them convey effectively the semantic load of both of the two possible percepts. In order to do that, they could take into account bottom-up modulating factors related to salient visual elements, and, subsequently, to ocular fixations guided by the design itself. This is consistent with the fact that eye-tracking studies and cognitive sciences offer, from their models, paradigms and instruments, new possibilities to study brand design phenomena (Plassmann et al., 2015). Likewise, this kind of studies can contribute, as discussed in previous paragraphs, to push back the frontiers of scientific knowledge (Casado-Aranda et al., 2020), within the scope of the decoding of visual brand designs. Besides, the use of eye-tracking methods is useful to choose an effective logotype when the graphic designer has different designs to be approved. As Rosenlacher and Tichý (2021) stated, attentional factors associated with the understanding of a logotype can be studied by using eye-tracking techniques. Due to the fact that these factors exert an influence on the communicative performance of a logotype, it is practical to conduct tests by which observer's eye-movements lead to improve the design in terms of its efficiency (Rosenlacher and Tichý, 2021).

Conclusions

Bistable logotypes have bottom-up modulating areas that can exert an influence on their perception. According to the findings, ocular fixations made in certain areas of a bistable brand design are related to the recognition of dominant images that are perceived during the exposure of the ambiguous stimulus. This fact should be assumed as relevant for graphic designers involved in the conception and creation of this type of images. In short, it is recognized that ocular fixation areas interfere in the way a bistable brand image is interpreted. On the basis of the foregoing, graphic designers who design bistable logos to convey two different meanings, should take into account that specific features of the image designed can direct observer's attention in such a way that bottom-up modulating processes arise, conditioning, this way, its final perception and its dominant final recognition.

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