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Perceptual reversals and time-response analyses within the scope of decoding a bistable image

Análisis de reversibilidades perceptuales y de tiempos de respuesta en el marco de la decodificación de una imagen biestable

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Abstract

A bistable image admits two possible interpretations, so that the observer can recognize the two percepts, but never at the same time. The alternations between percepts are called "perceptual reversals". When the observer's position is different from the upright position, the ability to make perceptual alternations may be impaired. Besides, the recognition of the percepts of a bistable image can be a complex reaction time visual task, if it involves recognizing two different conceptual units, added to the fact of having to make a subsequent report. A visual task was performed by 88 people in order to establish whether the perception of Boring's bistable image *My girlfriend or my mother-in-law* is associated with areas that condition its interpretation. It was assumed that decoding the image and reporting the perceived percept implied a complex reaction time. The task itself was done in front of a fixed 120 Hz eye-tracker, in two opposite body positions. Analyses were made reviewing the association of the percepts with bottom-up modulation areas of the image, and considering ocular fixations made 200 and 250 milliseconds before the time of the report. The records of these fixations were obtained so as to establish which of the two reaction times (200 ms or 250 ms) was involved in the bottom-up modulation process from the moment of ocular fixation to the reports given by the participants. It was concluded that perceptual reversals decrease significantly when head idiotropic axis points in the gravity vector direction, in comparison to the upright position. Likewise, associations between

visual percepts and bottom-up modulating areas of the image were found when analyses were done by considering ocular fixations made 250 ms before the moment of the report. Interpreting Boring's bistable image implies a complex visual task in accordance with the results obtained.
Keywords: bistable perception, perceptual reversals, ocular fixations, time reaction, body orientation.

Resumen

Una imagen biestable admite dos interpretaciones, de modo que el observador reconoce cada percepto, pero nunca los dos al mismo tiempo. Cada alternancia entre uno y otro percepto se conoce con el nombre de "reversibilidad perceptual". Este tipo de percepción, denominada también "biestable", puede implicar dos tipos de modulación, una mediada por las características físicas del estímulo visual y por las áreas de fijación ocular, y otra por información contextual o por conocimiento almacenado en memoria. En ese sentido, las alternancias perceptuales que se manifiestan durante la observación de una imagen biestable pueden estar condicionadas por la manera en que el observador recorre con su mirada el estímulo biestable, de manera tal que es manifiesta una asociación entre específicas áreas de la imagen y el percepto que se reconoce. En efecto, para la imagen biestable de Boring *Mi novia o mi suegra*, se han establecido áreas de fijación ocular que favorecen los dos posibles perceptos (una mujer joven y una mujer de edad). Algunas de estas zonas elicitan más la interpretación de uno de los perceptos, otras de los dos indistintamente, como se reconoce en estudios precedentes. Por otra parte, se ha encontrado evidencia de que cuando la posición corporal del observador es distinta a la posición erguida (el tronco y la cabeza alineados con la vertical), puede dificultarse la capacidad para hacer las alternancias perceptuales. La rotación del eje idiotrópico de la cabeza con respecto al vector que apunta verticalmente hacia el cénit tiene repercusiones en los procesos perceptuales visuales y también en la manifestación de las reversibilidades perceptuales inherentes a la observación de imágenes biestables. El reconocimiento de los perceptos de un estímulo visual biestable puede suponer una tarea visual de tiempo de reacción complejo (superior a 230 milisegundos), dado que esta implica reconocer dos unidades conceptuales diferentes. A esto se suma el hecho de tener que hacer un reporte posterior que implique eferencias motoras. A los efectos de establecer si la percepción de la imagen biestable *Mi novia o mi suegra* está asociada a las áreas del estímulo que condicionan su interpretación cuando se asume que su decodificación más su reporte implican un tiempo de reacción complejo, se hicieron análisis de tareas visuales realizadas por 88 personas frente a un *eye-tracker* fijo de 120 Hz en dos posiciones corporales opuestas (una, con el tronco erguido y el eje idiotrópico de la cabeza apuntando hacia el cénit, y otra con el vector idiotrópico de la cabeza apuntando hacia el suelo en paralelo al eje gravitacional). Se revisó la asociación de los perceptos con las áreas de modulación de la imagen y considerando las fijaciones oculares realizadas 200 y 250 milisegundos antes del momento del reporte, el cual fue realizado por cada participante mediante el uso de los botones de un dispositivo conectado al registrador de datos. Los registros de fijaciones oculares, tomados en dos momentos previos al momento del reporte de los perceptos identificados, fueron considerados para establecer cuál de los dos tiempos de reacción (200 ms o 250 ms) está implicado en el proceso de modulación *bottom-up* desde el momento de la fijación ocular hasta el reporte dado por los participantes. Se concluyó que las reversibilidades perceptuales disminuyen significativamente cuando el eje idiotrópico de la cabeza apunta en el sentido del vector gravitacional en comparación con la posición erguida. Se encontraron asociaciones entre los perceptos y las áreas

de modulación cuando en el análisis se consideran las fijaciones oculares registradas, 250 milisegundos antes de los reportes. La interpretación de la imagen analizada supone una tarea visual compleja de conformidad con los resultados, pues el análisis de asociación entre perceptos reportados y áreas moduladoras que arroja significancia es el que se hace revisando las fijaciones oculares hechas 250 ms antes del registro del reporte de cada percepto.
Palabras clave: percepción biestable, reversibilidades perceptuales, fijaciones oculares, tiempo de reacción, orientación del cuerpo.

Introduction

Bistable perception and perceptual reversals

Bistable perception is the perceptual phenomenon by which an observer interprets the same stimulus in two different ways (Borisyuk et al., 2009; Clément & Demel, 2012; Pressnitzer & Hupé, 2006). Keeping the stimulus unchanged, the observer changes from one interpretation to another because the stimulus offers several ways to be interpreted (Brascamp, Sterzer, Blake, & Knapen, 2018; Moreno-Bote, Rinzel, & Rubin, 2007). Besides, the two possible visual percepts cannot be perceived simultaneously (Leopold & Logothetis, 1999; Weilnhammer, Stuke, Hesselmann, Sterzer, & Schmack, 2017). Given the fact that bistable visual stimuli admit two possible percepts (Sterzer, Russ, Preibisch, & Kleinschmidt, 2002), or more than two, in the case of multistable images (*e. g.* Huguet, Rinzel, & Hupé, 2014; Wallis & Ringelhan, 2013), they are also called ambiguous images (Gijs & van Ee, 2006).The phenomenon of visual perceptual bistability can also be known as visual bistability (Intaité, Kovisto, & Castelo-Branco, 2014), where by the perceptual switch emerges between the possible percepts, a change that is known as perceptual reversal (Clément & Demel, 2012). These alternations between one percept and another lead to bistability occurrence (Denham, Bendixen, Mill, Tóth, Wennekers, Coath, Böhm, Szalardy, & Winkler, 2012), which is caused by an alteration in observation patterns (García-Pérez, 1989). It has been stated that physical characteristics of bistable images arouse ambiguity, so that the resulting perceptual configuration depends, not only on the way in which the stimulus is being observed, but also on the areas of the image by which the eyes make fixations (*e. g.* Chastain & Burnham, 1975; Gale & Findlay, 1983; García-Pérez, 1989; Hsiao, Chen, Spence, & Yeh, 2012; Raftopoulos, 2011). Thus, a bottom-up modulation of visual perception is involved, (Hsiao et al, 2012; Meng & Tong, 2004). On the other hand, it has also been shown that bistable visual perception is conditioned by processing information that comes from concepts and previous knowledge capable to be integrated with visual perceptual processes (Intaitė, Noreika, Šoliūnas, & Falter, 2013). As regards, what is implied is a top-down processing, where the interpretation of the bistable stimulus is established by information previously stored in memory (Sterzer, Kleinschmidt, & Rees, 2009). As a consequence, perceptual reversals occur not only due to simple bottom-up processing, but also because of cognitive mechanisms involved in top-down visual processes (Intaitė et al., 2013). Besides, cognitive factors that may contribute to bistable perception include expectancy effects, volitional effects, knowledge about making reversals and familiarity with perceptual reversibility (Long & Toppino, 2004).

Ocular fixations in bottom-up modulating areas

Crucial fixation points in the field of vision can influence the perceptual organization of a bistable stimulus (Raftopoulos, 2011). In other words, the way a bistable image is visually interpreted depends on where the observer fixes his/her attention, because there are crucial ocularfixation points that exert a serious influence on the perceptual interpretation (Hsiao et al., 2012; Peterson & Gibson, 1994; Rodríguez-Martínez & Castillo-Parra, 2018a). As regards, attention allows selecting relevant information for the development of perceptual tasks (Stelzer, Andrés, Introzzi, Canet-Juric, & Urquijo, 2019). Gale and Findlay (1983) demonstrated that there are critical areas that favor the perception of each possible percept of an ambiguous figure. Having done a graphic synthesis of the Boring´s image "My girlfriend or my mother-in-law", their study referred to four specific areas, each of them with useful visual information for the recognition of percepts. Thus, ocular fixation areas were considered to favor one percept more than the other one. The conclusions suggested that the strokes designated as "M" (area A3) had a propensity to favor the old woman percept, while the strokes called "YE" (area A1) favored recognition of the young lady (see figure 1).

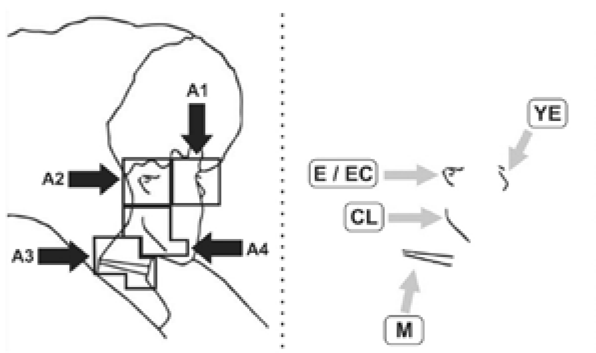

Figure 1. Bottom-up modulation areas and traces of Boring's image.

On the left, based on the model used by Gale and Findlay (1983), and also by Marroquín-Ciendúa, Rodríguez-Martínez, and Rodríguez-Celis (2020), four critical areas of interest are shown. Area A1, modulating for the young lady percept, contains defining lines of the young woman's eye and nose; A2 defines the young woman´s ear, and also the old woman´s eye; A3 area modulates old woman percept, referring to old woman´s mouth; A4 area has a line that defines the old woman's nose and, in turn, an outline of the young woman's jaw. On the right, the traces that were manipulated by the researchers Gale and Findlay (1983) can be seen, defining 4 critical features regarding the interpretation of the image. "M" traces (within A3 area) mostly elicits the old woman´s percept, while YE lines favor the young lady percept. From these findings, the areas defined in the image (see on the left) were settled. Image adapted from Gale and Findlay (1983).

Body spatial position and its effect on both ocular fixations and perceptual reversals

Various studies have sought to establish whether there is an effect between the gravitational orientation of the body and the perceptual configurations manifested during the observation of bistable images. Yamamoto and Yamamoto (2006) examined the effect of modifying the relation between gravity vector and vertical direction by changing body posture but remaining constant (on retina) bistable visual stimuli. They studied the effect of gravity in different body positions, arguing that the perception of a reversible figure may involve a multimodal integration of the vestibular, proprioceptive, and tactile systems. Clément and Eckardt (2005) made significant contributions regarding the interpretation of stimuli when they remain static while the body rotates. They found that up to certain degrees of rotation, the phenomenon of perceptual equivalence is present, especially when the head reaches up to 45 degrees with respect to a base position of non-inverted verticality. Their results showed that in the upright position observers claimed that they were able to recognize two percepts of a bistable image better than in the on-side or supine orientations. The fact that a proximal stimulus varies significantly according to changes in body posture exerts an influence on visual perception (Clément & Eckardt, 2005). On the other hand, ambiguous directions top/down or right / left of perspective bistable images are determined with respect to the position of observer´s body (Raftopoulos, 2011). As far as ocular fixations are concerned, the compensation mechanisms that starts to be activated while rotating the head idiotropic vector can influence the occurrence of ocular fixations because eyes tend to be moved towards the plane in which the head has been rotated (Crawford & Vilis, 1991). Likewise, observers make saccadic eye movements while rotating (Mackrous & Simoneau, 2011), in order to compensate the change that is made due to the variation of the visual field in relation to the visual perception of the world in the up-right position (López, Bachofner, Mercier, & Blanke, 2009; MacDougall & Curthoys, 2012). In addition, the fact that a proximal stimulus significantly varies due to the changes experienced in terms of gravitational orientation may have an effect on the perceptual processes while processing a bistable visual stimulus (Clément & Eckardt, 2005; Yamamoto & Yamamoto, 2006). When idiotropic head axis is inverted, eye's vertical meridians rotate in relation to gravity vector. This fact, in turn, exert an influence on visual processing (Gaunet & Berthoz, 2000). This particular perceptual configuration may produce a relative difficulty while processing visual information (Arleo & Rondi-Reig, 2010). Besides, compensatory eye movements are made as a result of the processing of vestibular information (Mackrous & Simoneau, 2011). These compensatory ocular movements emerge due to the activation of involuntary adaptation mechanisms (Israël, Ventre-Dominey, & Denise, 1999). In addition, there is a reflex action that emerges so as to both stabilize the image and favor the perceptual process to be more efficient (Angelaki, Klier, & Snyder, 2009). Interactions between objects and observers are achieved through complementary processes of assimilation and accommodation (Balint & Hall, 2015). As far as assimilation is concerned, interaction with the object is approached through previous experiences. For its part, accommodation involves revision of an old schema in order to fit a new perceptual experience (Balint & Hall, 2015). These facts might be implied while rotating the head idiotropic vector so as to identify images located in the visual field (Lopez et al., 2009).

Reaction time measures

The approach to reaction times in psychological research has taken many years of experimental research (*e. g.* Robinson, 2001). Indeed, reaction time has become an important topic of research for experimental psychologists since middle of 19th Century (Ashoke, Shikha, & Sudarsan, 2010). Reaction time is a key variable to understand information processing carried out by the central nervous system while being exposed to a stimulus (Marini, Ars, Ferrer, & Bonnet, 2004). As a matter of fact, reaction time measures show variability between individuals. They are also conditioned by both the sensory modality of the stimulus and the cognitive load involved in the task (Noorani & Carpenter, 2016). Several types of reaction times have been identified such as simple reaction time, recognition reaction time, and choice reaction time (Ashoke et al., 2010). Simple reaction time is the minimum time required to respond to a signal (Bonnet, Gurlekian, & Harris, 1992; Pain & Hibbs, 2007, Tolhurst, 1975). Such a reaction time is taken to be the time required for the transmission of a fixed quantity of information (Norwich, Seburn, & Axelrad, 1989; Robinson, 2001).Thus, the participant indicates as quickly as possible when a stimulus appears, so that a low reaction time obtained from a well-trained participant ranged from 180 to 200 milliseconds (Shelton & Kumarose, 2010; Thompson, Colebatch, Brown, Rothwell, Day, & Marsden, 1992). Subsequently, simple reaction time is understood as a detection task that involves only the detection of the appearance of stimuli (Bonnet, Gurlekian, & Harris, 1992; Bonnet 1994; Henry & Rogers, 1960). It has also been stated that a simple reaction time entails a fast route for one-choice reaction time which could last 180ms, whereas a complex reaction time regarding two or more choices implies lapses from 220ms to 250 ms (Frith & Done, 1986; Pins & Bonnet, 1996). Thus, complex reaction time involves a choice reaction time (Jahanshahi, Brown, & Marsden, 1992). Besides, complex reaction time tasks that incorporate a strong semantic component imply a choice reaction measure (Adam, 1999). This fact, in turn, entails efferences that bring about decision making (*e. g.* Gursoy, 2010). On the other hand, the triggering of a motor response given as a consequence of the recognition of a stimulus under optimal attention conditions may imply a span of more than 200 ms latency (*e. g.* Bloxham, Dick, & Moore, 1987). This time is longer for visual stimuli than for auditory or proprioceptive ones, due to the greater number of synapses that should be created in the dorsal pathway (Pérez-Tejero, Soto-Rey, & Rojo-González, 2011).

The simple reaction time for visual stimulation tends to range from 180 to 200 ms (Ashoke et al., 2010; Shelton & Kumarose, 2010). Furthermore, if the task requires identification, categorization or choice, milliseconds will have to be added, in ranges of between 20 to 50 ms (time added in relation to simple reaction time). It implies that there is a difference between choice reaction time and simple reaction time (Klapp, Abbott, Coffman, Greim, Snider, & Young, 1979). Additionally, reaction time measures show variability between individuals, despite the fact that they can be conditioned by both the sensory modality of sensory stimuli and the cognitive load of the experimental task (Noorani & Carpenter, 2016).

Considering bistable images, they imply the simultaneous presence of two percepts, where it is only possible to recognize one of them in a given period of time, but never both at the same time (Leopold & Logothetis, 1999). In this sense, when it comes to responding to the identification of one or the other percept, a choice reaction time paradigm is involved (Logan, Cowan, & Davis, 1984), beyond the fact that the stimulus is only one. The bistability involves the particularity of being able to have two different percepts. Thus, for each response corresponding to each perceptual identification, a particular reaction time will correspond (Clément & Demel, 2012). Subsequently, when instructed to give a different response for each percept of a bistable image, the choice reaction model is implied (*e. g.* Logan et al., 1984), given the fact that the observer emits a different response to each possible perceptual performance referring to each possible interpretation (Hsiao et al., 2012). As regards, a two-choice response time is implied, which leads to the fact of anticipating the stimulus, which, in turn, exerts an influence on response time (*e. g.* Frith & Done, 1986). The study of the relationship between reaction times and bottom-up mechanisms involved during the decoding of bistable images is of great relevance within the scope of perception psychology (*e. g.* Marroquín-Ciendúa et al., 2020). The modulating mechanisms of bistable perception have been studied for decades, because perceptual bistability contributes, as a paradigm, to the understanding of various psychological processes (Rodríguez-Martínez & Castillo-Parra, 2018a). Besides, visual bistability has been used so as to study the neural correlates of consciousness (Sterzer et al., 2009). Which areas of a bistable image are seen when analyzing ocular fixations that occur milliseconds before the reports concerning recognized percepts? What role do reaction times play in the study of bottom-up modulation mechanisms involved in bistable perception? Examining these relevant issues, and also studying them in relation to different body positions, allows expanding the frontiers of knowledge in line with the importance of the notion "perception for action" (*e. g.* Rodríguez-Martínez & Castillo-Parra, 2018b) within the understanding of human behavior.

The purpose of the study that is outlined here was to establish whether the manifestation of perceptual reversals varies when an observer looks at the Boring´s bistable image in the up-right position compared to when such image is observed when head idiotropic axis is inverted (pointing to the ground). It was also wanted to observe whether in consideration of the eye fixation records taken 200 ms before reporting the percept, the association between the reports and the bottom-up modulation areas varies with respect to the correspondence for observations of oculo - motor activity taken 250 ms before the report, taking into account both the up-right position and the one in which head idiotropic axis is inverted. These aims were defined considering that the reports given could have implied a difference of 250 ms from the identification of the percept to the subsequent reporting by motor route. It was hypothetically assumed that no associations would be found between the reported percepts and the bottom-up modulating areas if a simple reaction time was assumed as the basis to analyze the eye´s fixation place in relation to the reported visual percept. On the contrary, given that the identification and reporting of the percepts of Boring's bistable image should involve a complex reaction time task (or choice reaction time), it was estimated that when doing the analyzes considering ocular fixations made 250 ms before the time the percept report was recorded, a significant association would be found between percepts and the bottom-up modulating areas.

Methods

Participants

Eighty-eight paid volunteers participated in this study (average age, M = 21.56, SD = 3.68.; 54.55 % women; 45.45 % men). All of them reported not having had medical histories concerning cognitive impairments, vestibular system damages or vertigo disorders. All participants did not have visual impairments. They gave informed consent prior to the experiment. This study was approved by the ethical committee of the University Jorge Tadeo Lozano. The sample was divided in two groups: the first one (44 participants) had to carry out the task in a body position in which the orientation was defined by the parallelism between the up-right direction and the head idiotropic vector. This position was called up-right position (URP). The second group (the other 44 participants) performed the task in a position that corresponded with a vector opposition between up-right direction and the head idiotropic vector. This position will be named as gravity vector aligning position (GVAP) from here on in.

Procedure

All the participants (both groups) were placed so that their faces were parallel to the monitor of a reference standard Tobii™ T120 eye-tracker device. As for the calibration phase, a viewing distance of 60 cm was the measurement deemed appropriate for all the subjects (*e. g.*, Marroquín-Ciendúa et al., 2020). The participants viewed the bistable image "My girlfriend or my mother-in-law" (the simplified version used by Gale & Findlay, 1983). By clicking a mouse bottom, each participant had to report the perceived visual percepts that they identified. Thus, participants had to continuously report the visual percepts, saying "young" or "old", as appropriate. These reports were given each time participants began a perceptual recognition.

By registering visual percepts, it was possible recording perceptual reversals. The bistable image was presented to each participant for 15 seconds. Prior to presenting the ambiguous image, a fixation point was exposed for 200 ms. This fixation point was neutral so as not to favor perception of either of the percepts. It was placed in the leftmost border point of areas A2 and A4defined by Gale & Findlay (1983). Areas of interest (AOIs) and neutral fixation point are illustrated in figure 2 (B). The procedure is also illustrated in figure 2 (A).

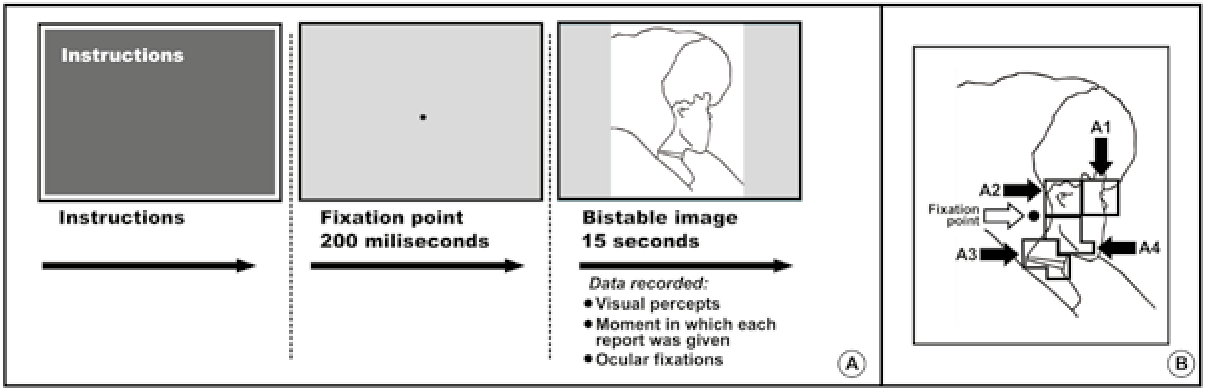

Figure 2. A) The visual task performed by participants on the eye tracker´s screen. B) The bistable image used with its modulating bottom-up areas plus the neutral fixation point (see it on the left-most border point just between A2 and A4 areas).
Source: Own design.

Data analyses

The records were refined so as to generate a data table in which the following data were outlined: 1. Perceptual reports (old woman or young woman); 2. AOIs (areas of interest viewed); 3. Ocular fixations records taken 250 ms before perceptual reports were registered; 4. Ocular fixations records taken 200 ms before perceptual reports were registered. Based on these records, the perceptual reports were shown in a data table for each participant, specifying the area of interest that was being viewed considering both 250 ms and 200 ms before the recording of each report. The ocular fixations taken 200 and 250 ms before the moment of each report were considered due to the fact that there are time-differences between each record of each report and the moment in which ocular fixations were performed. It was done so as to establish which of the two reaction times (200 ms or 250 ms) was involved in the bottom-up modulation process (from the moment in which ocular fixations were made to the time in which reports were given by the participants). According to scientific literature, by taking into account ocular fixations made 250 ms before reports, there should be an association between perceptual reports and modulating bottom-up areas of the bistable image, due to the fact that recognizing bistable images imply a complex reaction time (*e. g.* Marroquín-Ciendúa et al., 2020). It was also hypothesized that for ocular fixations made 200 ms before reports there would not be significant associations between modulating bottom-up areas and reported percepts, due to the fact that identification of each percept did not imply a simple reaction time. The analyses were done by using SPSS software (v.23 for Windows).

Results

It was determined that the data was not normally distributed when implementing Kolmogorov-Smirnov statistical test ($p < .05$), neither for the number of reports of visual percepts nor for the number of perceptual reversals. Subsequently, it was necessary to implement the U Mann-Whitney statistic test (table 1). No evidence was statistically found to reject the hypothesis of equality in the distribution (Mdn = 1.00; U = 3392; p = .106) of the reported visual percepts between URP group (M = 2.25, SD = 2.156) and GVAP group (M = 1.52, SD = 1.005). The analysis made using the data referring to perceptual reversals showed that the difference in favor of the URP group (M = .97, SD = 1.854) compared to the values recorded among the participants of the GVAP group (M = .25, SD = .572) was significant (Mdn = .00; U = 3191; p = .009).

Table 1
Results for perceptual reversals and visual percepts reported comparing URP and GVAP groups.

	URP reversals	**GVAP reversals**	**URP percepts**	**GVAP percepts**
M	.97	.25	2.25	1.52
SD	1.854	.572	2.156	1.005

Note: As for comparison between reversals there was statistical significance (Mdn = .00; U = 3191; p = .009). As far as comparison of percepts reported is concerned, there was no statistical significance (Mdn = 1.00; U = 3392; p = .106).

On the other hand, the ocular fixations made on areas of interest in correspondence with the reported percepts are presented in the following tables. It was taken into account that ocular fixations in such areas were taken 250 ms (table 2) and 200 ms (table 3) before each reported visual percept. Young woman percept was coded as “YW”; Old woman as “OW”.

Table 2
Visual percepts related to AOIs 250 ms before reports.

Group	**AOIs**	**YW**	**YW (%)**	**OW**	**OW (%)**
URP	A1	46	79	12	21
	A2	44	49	46	51
	A3	5	33	10	67
	A4	8	40	12	60
	Background	20	65	11	35
GVAP	A1	33	73	12	27
	A2	29	49	30	51
	A3	1	33	2	67
	A4	6	60	4	40
	Background	14	56	11	44

Table 3
Visual percepts related to AOIs 200 ms before reports.

Group	AOIs	YW	YW (%)	OW	OW (%)
	A1	43	57	33	43
	A2	41	66	21	34
URP	A3	9	56	7	44
	A4	11	38	18	62
	Background	19	68	9	32
	A1	30	73	11	27
	A2	27	48	29	52
GAVP	A3	1	33	2	67
	A4	8	53	7	47
	Background	14	61	9	39

When comparing ocular fixations taken 250 ms before the report of visual percepts with records taken considering 200 ms before the report, the results showed that the fixation areas referred to the reported percepts were associated with such reports, when the record of ocular fixation was taken 250 ms before recording the report [$\chi 2$ (4, N = 356) = 25.968, p < .001]. When the record of ocular fixation was taken 200 ms before recording the report, no significant association was found [$\chi 2$ (4, N = 349) = 6.069, p = .194]. Looking specifically at the analysis for each of the body positions, it can be seen that for eye fixations records taken 200 ms before registering the reported percept, no significant associations were found (for URP, χ^2 (4, n = 211) = 7.684, p = .104; for GVAP, χ^2 (4, N = 138) = 7.035, p = .134. When taking eye fixations 250 ms before registering the percept, significant associations were found for the URP group [χ^2 (4, n = 214) = 20.734, p < .001], but not for the GVAP group [χ^2 (4, n = 142) = 7.055, p = .133]. The statistical significances are shown in table 4.

Table 4
Association between eye fixations 250 and 200 ms. before reporting percepts.

	Total (-250 ms.)	URP (-250 ms.)	GVAP (-250 ms.)	Total (-200 ms.)	URP (-200 ms.)	GVAP (-200 ms.)
χ^2	25.968	20.734	7.055	6.069	7.684	7.035
df	4	4	4	4	4	4
Sig.	.000*	.000*	.133	.194	.104	.134
N	356	214	142	349	211	138

*p < .05

Discussion

Regarding the analysis relating perceptual reversals, although there was not normality concerning data distribution, the results indicate that there was a greater manifestation of the alternances in the observations of the bistable stimulus made by the participants of

URP group in comparison with those reported by GVAP group. Clément and Eckardt (2005) had already suggested that a change in position with respect to the vertical direction had an impact on perceptual reversals. Besides, visual perception performance during the observation of bistable images is affected as a result of the rotation of the idiotropic head axis without there being a modification of the proximal stimulus (Yamamoto & Yamamoto, 2006). Various questions should be addressed in view of these results. Firstly, while the visual stimulus for GVAP group was placed at the same distance and position in order to make the proximal stimulus equal relative to URP group, certain information of alothetic nature (information, cues and signals that come from the environment) gave the participants the spatial perception of vector parallelism between the G vector and the idiotropic head axis, such as the referencing of the eye-tracker device within the environment. This special perceptual configuration can produce a relative difficulty when processing visual information, as Arleo and Rondi-Reig (2010) stated. Likewise, compensatory ocular movements made as a result of the processing of vestibular information occur as a reflex action to stabilize the image and also to favor the perceptual process in terms of making it more assertive (Angelaki et al., 2009). Given that there are saccadic movements that are made so as to compensate the change in the visual field relative to the visual perception in the up-right position while rotating (Mackrous & Simoneau, 2011), there is an impact on the way observers make perceptual reversals while they are viewing at a bistable image in a different body position relative to the upright one (*e. g.* Clément & Eckardt, 2005; Yamamoto & Yamamoto, 2006). On the other hand, the opposition of head idiotropic axis with respect to the vertical direction affects the perception of visual stimuli due to the assimilation and accommodation processes that, in turn, entail the incorporation of the allusive information to the atypical body position, even when the proximal stimulus was the same in a normal body position (Yamamoto & Yamamoto, 2006). Given that interactions between the object and the observer are achieved through assimilation and accommodation (Balint & Hall, 2015), it is possible that, for the participants of the GVAP group, an adaptation mediated by assimilation emerged. This fact brings about a process of apprehending the experience with reality, exerting, in turn, an influence on the way of making perceptual reversals. When human beings perceive visual stimuli in body positions that are non-typical in relation to the corporal orientation in which these stimuli are usually perceived, both the assimilation and accommodation processes certainly involve the incorporation of allusive information relating body orientation, even when the visual stimulus, in retina, is the same as the one observed in the up-right position (Yamamoto & Yamamoto, 2006). Perceptual visual performance is not the same when idiotropic head axis is inverted as a consequence of eye's vertical meridians are rotated in relation to the gravity vector (Gaunet & Berthoz, 2000). A difficulty emerges in making perceptual reversals, as found not only in the present study, but also in previous research projects conducted by Cément and Eckardt (2005), and Yamamoto and Yamamoto (2006).

As for the correspondence between reported percepts and ocular fixations made in bottom-up modulating areas, it was found that the fixation visual areas referred to the reported percepts were associated with these reports when the record of ocular fixations were taken 250 ms before recording the percepts reported. These results are in line with the findings provided by Marroquín-Ciendúa et al. (2020). They also found that ocular fixations taken 250 ms before the reports are associated with bottom-up modulating areas. On the other hand, when records of ocular fixations were taken 200 ms before each report was recorded, no significant association was found. Considering the analysis carried out on all the reports of registered percepts, it was found that the association between the correspondence of the reported percepts with the fixations carried out in bottom-up modulating areas was significant ($p < .001$), when the fixation area was taken 250 ms before the perceptual report was made. In contrast, the association was not significant ($p = .194$), when the fixation area was taken with a difference of 200 ms between the ocular fixation and the record of the report. It has to be considered that stimuli of a bistable nature imply the simultaneous presence of two stimuli united in one. As regards, it is only possible to recognize one of them in a given lapse but never both at the same time (Leopold & Logothetis, 1999; Weilnhammer et al., 2017). Thus, when one of the possible percepts should be identified, a choice reaction time paradigm is incurred (Logan et al., 1984). Additionally, the movement response time must be estimated (clicking on the computer mouse), that is, the time required by each participant to complete the task. Subsequently, the response time implied a reaction time that involved an efference (*e. g.* Gursoy, 2010). The visual task involved a response that implied additional processing to the mere detection of the appearance of the stimulus. It happened due to the need to identify or categorize the percepts included in the bistable visual stimulus. Having to recognize and identify the percepts increased the reaction time, and therefore the time of movement, at values that could range from an additional 20 to 50 milliseconds (*e. g.* Frith & Done, 1986; Klap et al., 1979) compared to simple reaction times, estimated in ranges of 180 to 200 ms (Shelton & Kumarose, 2010). Based on the visual task used and reviewing the results obtained in terms of associations between ocular fixations and critical modulating bottom-up areas, it can be inferred that the ocular fixations recorded 250 ms before registering the reports corresponds to the bottom-up modulation phenomenon. As Gursoy (2010) points out, the triggering of the motor response as a consequence of the recognition of the stimulus in optimal conditions of attention can imply more than 200 ms latency (Pins & Bonnet, 1996). In methodological terms, it was estimated that to review the ocular fixation areas associated with the percepts, it was necessary to take into account ocular fixations made 250 ms before recording the report. The comparison was also made with the fixation areas observed 200 ms before the records of percepts in order to observe whether or not there was indeed a disparity between the areas of fixation corresponding to congruent percepts from what previous studies indicated (in terms of the congruence between ocular fixation areas and the reported percept). The results found from the analysis of all the ocular fixations with correspondence in terms of the bottom-up modulation and the reported percept support the difference between simple reaction times for visual stimulation, oscillating between 180 and 200 ms (Ashoke et al., 2010; Thompson et al., 1992) and complex reaction times, which can suppose additional 50 ms, reaching values of approximately 220ms (Frith & Done, 1986) or higher (*e. g.* Pins & Bonnet, 1996). It was found that for the recording of eye fixations 200 ms prior to registration of the percept report, there were no significant associations in any of the two body positions. However, in the case of recording eye fixations 250 ms before registering the percept, there were significant associations in the URP group, but not for the GVAP group. This fact can be explained on the basis of proximal stimulus varies in accordance with the positional changes that human body experiences, which, in turn, exerts an influence on visual perceptual processing, as Yamamoto and Yamamoto (2006) stated. The modulation that gravitational orientation can have on the visual perception of bistable images is based on visual, vestibular and proprioceptive multimodal integration models (Clément & Eckardt, 2005; Yamamoto & Yamamoto, 2006). Besides, it might be related with the affectation that occur in terms of compensatory eye movements (MacDougall & Curthoys, 2012) as a consequence of the activation of involuntary adaptation mechanisms (Israël et al., 1999).The association cortex, in which the visual information evoked by bistable images and information about other sensory inputs that are related to body posture may converge, is a region in the brain where visual processing can be influenced by information concerning vestibular, proprioceptive, and tactile information (Yamamoto & Yamamoto, 2006). According to the results, when analyzing associations between ocular fixations (taken 250 ms before the moment of the reports) in bottom-up modulating areas with perceptual reports, it is noted how there was no statistical significance corresponding GVAP group unlike results for URP group. Besides, when analyzing each group considering ocular fixations made 200 ms before the reports, there were no statistical significances for both URP and GVAP groups. It underlines that the association between fixations and perceptual reports regarding both time response and body position emerged when the observer viewed the Boring´s bistable image in the up-right position (only when considering ocular fixations made 250 ms before the time in which the reports of the visual percepts were made). It lends support to the fact that the recognition of the percepts relating to this bistable image is linked to a complex reaction time. In addition, it might be assumed that the up-right position is more suitable for identifying percepts from ambiguous images concerning bottom-up modulating areas. Taking into account that changes in the way of interacting with the environment will be seen in the future, where unusual body positions could be a relevant aspect if considering that expanding humanity into space is something inevitable (Balint & Hall, 2015), it is necessary to study the modulatory bottom-up perceptual mechanisms considering both time reaction and gravitational orientation of human body. The processes involved in receiving information from the outside world and their respective processing can be outlined in models that claim the notion of perception for action, where by there is an interaction between reality, sensory receptors and, subsequently, multisensory perceptual processes (Rosa, Oliveira, Alghazawi, Fardoun, & Gamito, 2017). Given the fact that the study outlined here has some limitations in terms of the number of body positions involved as well as the quantity of subtractions in milliseconds (just 200 and 250 ms) taken from the reports so as to compare different moments in which ocular fixations were made in relation to the reported visual percepts, further studies will have to be planned so as to conduct experiments that include more body spatial orientations considering other time-lags regarding reports in correspondence with gazing at bottom-up modulating areas of bistable images.

Conclusions

Perceptual reversals are less manifested when observers look at Boring's bistable image in a position where head idiotropic axis points in the direction of the gravity vector in comparison to the up-right position. Associations are found between bottom-up modulating areas of the bistable figure and the percepts reported when analyses are made assuming that the task of interpreting the visual stimulus is, indeed, a task that involves a complex reaction time. By considering ocular fixations recorded 200 ms before the moment in which the report of the perceived percept is registered, it is not possible to find a level of association between visual percepts reported and the areas that modulate visual perception. The perception of Boring´s bistable figure implies a complex reaction time if considering that there is a significant association between the perception and eye-fixated bottom-up modulating areas of the image taking into account ocular fixations made 250 ms before the reported visual percept record. The up-right position is more proper for recognizing visual percepts from the bistable visual stimulus concerning bottom-up modulating areas of the ambiguous image. Considering that observing ambiguous figures implies various psychological processes, it is necessary to carry on studying bistable perception phenomenon. It will contribute to making progress in the understanding of perception psychology.

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