http://dx.doi.org/10.1590/0103-166X2014000300004

The hollow-face illusion monocularly observed in a box

A ilusão da máscara côncava observada monocularmente em uma caixa

Maria Amélia Cesari **QUAGLIA**[1]
Lívia da Silva **BACHETTI**[2]
Arthur **ALVES**[3]

Abstract

Under monocular conditions, 40 students observed the reverse of polychrome and monochrome masks and judged them to be concave, convex or flat. The mask was presented upright and illuminated from above, below, right and left and in the upside down position illuminated from below. The magnitude of the perceived depth or relief was estimated using a retractable tape measure. Regardless of color, lighting and orientation, the majority of responses indicated that the hollow masks were perceived to be convex. No significant differences were observed between the depth or convexity of the metric magnitudes and scalar magnitudes of the concave masks in relation to variations in the light source direction, color, and position. The illusory depth, seeing the concave mask as convex, is a robust phenomenon that suggests the predominant role of higher-order processes over the low-order processes in visual face perception.

Keywords: Face perception; Depth perception; Visual perception.

Resumo

Em condição de observação monocular, 40 estudantes universitários julgaram como côncavo, plano ou convexo os reversos de uma máscara monocromada e de uma policromada, iluminados por cima, por baixo, pela direita e pela esquerda, na posição vertical, e na posição invertida com iluminação por baixo. A magnitude da profundidade percebida foi estimada por meio de uma trena retrátil. Independentemente da cor, da iluminação e da orientação das máscaras, a maioria das respostas indicou que os reversos das máscaras foram percebidos como convexos. Não foram observadas diferenças significativas entre as magnitudes escalares e métricas de profundidade ou relevo das máscaras côncavas em relação às variações da direção da fonte de iluminação, cor e posição. A máscara côncava percebida ilusoriamente como convexa é um fenômeno robusto que sugere atuação predominante de processos de alta ordem sobre os processos de baixa ordem na percepção visual de faces.

Palavras-chave: *Percepção de face; Percepção de profundidade; Percepção visual.*

▼ ▼ ▼ ▼ ▼

[1] Universidade Federal de São João Del-Rei, Departamento de Psicologia, Programa de Pós-Graduação em Psicologia. *Campus* Dom Bosco, Praça Dom Helvécio, 74, Sala 2.17-A, Fábricas, 36301-160, São João Del-Rei, MG, Brasil. *Correspondência para*/Correspondence to: M.A.C. QUAGLIA. E-mail: <melinha@ufsj.edu.br>.
[2] Universidade de São Paulo, Faculdade de Filosofia, Ciências e Letras de Ribeirão Preto, Departamento de Psicologia. Ribeirão Preto, SP, Brasil.
[3] Psicólogo. Divinópolis, MG, Brasil.

Visual perception is bounded by neuroanatomical properties of the visual system. It starts with the projection of light passing through the transparent media of the eye and reaching the retina, where it is converted into electrical impulses that are carried to the occipital cortex through nerves and optic tracts (Lent, 2005). The processing of information that results from the physiological parameters of stimulus detection is called sensory, or bottom-up processing (Rossini & Galera, 2006). In this sense, the vision is a complex sensory modality divided into a number of different submodalities that represent various aspects of the external world, reflecting or emitting light (Lent, 2005). However, image perception does not depend only on sensorial, bottom-up, processes but also on cognitive, top-down, higher-order processes. Those top-down processes are responsible for the interpretation of sensorial signs through the person's perception and conceptual knowledge (Gregory, 1997). In the perceptive process we construct and test perceptual hypothesis based on perceptual facts, previous knowledge and inferences made based on higher order cognitive processes (Sternberg, 2008).

In the perception of depth and three-dimensional relief, both the illumination and shading of the objects are crucial. Klefner and Ramachandran (1992) and Ramachandran (1988) investigated these two factors and concluded that perception of the forms via shading is a global process in which all, or most, of the visual field takes part. Thus, the visual system seems to take into account only one source of illumination, coming from the top the object due to the solar illumination pattern. Moreover, a light source from above the hollow object, when inverted, elicits an inversion of visual depth and the object is perceived to be convex. The first report of this phenomenon occurred during the observation of cameos by Gmelin in 1744, perceived as alternately concave and convex, through variations in the lighting direction of the objects (Liu & Todd, 2004).

The phenomenon known as the hollow-mask illusion exemplifies the reversal of visual depth. In this case, observed from a distance, the reverse of a mask illuminated overhead is perceived as a convex face that is lit from below. The brain rejects the existence of concave faces interpreting the image as a convex face (Hill & Bruce, 1993). To enable the convex perception, a reversal in the direction of the source of illumination also occurs. The occurrence of this illusion is explained by the use of individual knowledge, cognitive or top-down processes, on faces (Hill & Johnston, 2007).

The prevalence of perceived convexities in concave objects when the light source is inaccurate was observed in the experiments of Hill and Bruce (1994), Hill and Johnston (2007) and Langer and Bülthoff (2001). Hill and Bruce (1994) studied the reversal of the binocular depth of a waved hemispherical object called "hollow potato". Unlike the concave mask, where reverse visual depth was stronger, greater distances were required for the illusion to happen in this object. However, the hollow potato was perceived as convex, indicating the strength of the illusory phenomenon despite the use of unfamiliar objects. Hill and Johnston (2007) found similar results when investigating the illusion using molds in the shapes of flower, a bear and waves. Observers perceived the illusory phenomenon, which required greater distances from the object for the less familiar wavy shape. Familiarity with the objects made the illusory perception stronger, however, it was not crucial to the reversal of visual depth. In both studies, the illusion was perceived even during the observation of objects unfamiliar to the observers. Langer and Bülthoff (2001) randomly presented images of concave, flat and convex irregular surfaces and also found a higher frequency in the perception of convexities than concavities in uncertain shading patterns shown in binocular condition.

Some factors facilitate the visual depth inversion in hollow faces. For example, Hill and Bruce (1994) and Hill and Johnston (2007) have shown, by progressively distancing the observer from the object, that the upright positioning of the hollow mask facilitates the illusory perception. The authors found a significant difference between hollow-mask perception in the upright and upside down orientations, and shorter distances were required for inverting the depth in an upright position. The results found by Papathomas and Bono (2004) corroborated previous findings. Through distancing and approximation from a tridimensional hollow-face mask, the illusory perception was stronger for the mask in an upright orientation, compared to upside down, both in the monocular and binocular observation conditions. Yoshida (2006) also found similar results using a psychophysics methodology. The direction of the light source was also a facilitator of binocular depth inversion in studies by Hill and Bruce (1993), Hill and Johnston (2007) and Yoshida (2006). In these studies, when the mask was illuminated from overhead, smaller distances were required for the hollow-face illusion to happen. Likewise, Hill and Johnston (2007) found that the color of the mask being close to the skin tone was also a facilitator of the binocular depth reversal. Another factor facilitating the reversal of visual depth was observing the concave mask in the monocular condition. The authors found a more prominent illusion in the monocular condition compared to the binocular condition because of the absence of binocular disparity (Hill & Bruce, 1993; Hill & Bruce, 1994; Papathomas & Bono, 2004).

Nevertheless, some factors precluded the reversal of binocular depth when observing a concave mask. Some psychopathological conditions, such as schizophrenic disorder (Dima et al., 2009; Dima, Dietrich, Dillo, Emrich, & Hinderk, 2010; Dima et al., 2011; Koethe et al., 2009; Schneider et al., 2002; Schneider, Leweke, Sternemann, Weber, & Emrich, 1996b) and alcohol withdrawal symptoms (Schneider et al., 1996a; Schneider et al., 1996b Schneider et al., 1998), prevented the occurrence of binocular depth inversion. Similar results were also found by studying sleep deprived individuals (Schneider et al., 1996b; Sternemann et al., 1997) and those under the psychotropic effects of cannabis (Emrich et al., 1991; Semple, Ramsden, & McIntosh, 2003) and nabilone, a synthetic cannabinoid (Leweke, Schneider, Radwan, Schmidt, & Emrich, 2000).

So far researchers have mainly addressed the reversal of visual depth. Quaglia and Fukusima (2009) aimed to investigate the metric and scalar perception of depth or relief in the concave mask. In this study the researchers used concave masks that were similar in size to an adult face and presented monocularly in a dark room. No significant differences were found among college students, in the metric allocation of perceived depth or relief in a concave mask that was monochrome or polychrome, illuminated from above, below, to the right and the left, with upright and upside down orientations. Similar results were found in the scalar assignments for the perception of depth or relief of the concave mask. The majority of the observers performed the monocular reversal of the concave mask, perceiving it as convex.

The present study aimed to reproduce the study by Quaglia and Fukusima (2009) in a reduced experimental condition, using a small concave mask in a box instead of a dark room. We planed to increase the knowledge of this visual phenomenon with different sources of illumination and facial characteristics, such as color and positioning, in both depth and relief perception of the hollow-face mask. In the present study a box with the stimuli inside and an interior light was used, as this could be a useful and convenient monocular observation instrument for research in small spaces.

Method

Participants

Forty undergraduate and graduate students of the *Universidade Federal de São João del-Rei* (UFSJ) participated in the experiment (14 men; 26 women); their ages ranged from 19 to 30 years and they all had normal or corrected vision acuity (6/6). All participants read and signed the Terms of Free Prior Informed Consent before taking part in the experiment.

Instruments

The Snellen scale was used to assess the visual acuity. An experimental box measuring 80 x

30 x 30 cm, with an observation hole of 0.5 mm in diameter, was constructed using Mediun-Density Fiberboard (MDF) to allow the participants to monocularly observe the concave mask. The reverse of a polychrome face mask of reduced size, 10 cm in height, 6.5 cm in width and 3 cm in depth, was painted with a natural skin tone. Eyes, mouth and eyebrows were outlined. The reverse side of a grey mask was also used. The masks were placed at a distance of 75 cm from the observation hole. To illuminate the mask in different directions, four 12 V lamps were positioned inside the box, above, below, to the left, and to the right of the mask, at a distance of 20 cm. A retractable tape measure was used by the observer to estimate in centimeters the depth or relief of the concave mask.

Procedures

After the participants had their visual acuity assessed, signed the terms of informed consent and received the instructions, each subject was asked to observe the mask with their preferential eye through the observation hole in the experimental box. The polychrome and monochrome masks were presented in a random order in the upright position (1) illuminated from above, (2) illuminated from below, (3) illuminated from the left, and (4) illuminated from the right, (5) and in the upside down position, illuminated from below. In each presentation condition the participant was asked to report the depth and relief perceived in the three tasks as follows. First, the participant was asked to judge the mask as either concave or convex. This task was also used to check if the participant understood the concave and convex concepts. Second, participants were asked to classify the perceived depth and relied on one of the following ordinal categories: (1) mask was totally concave, (2) partially concave, (3) flat, (4) partially convex, and (5) totally convex. Participants lastly estimated, in centimeters, using a retractable measure tape, the perceived distance between the tip of the nose and the base of the face mask.

This project was submitted and approved by the UFSJ Human Research Ethics Committee on April 17, 2013, No. 022/2013/CEPES/UFSJ. All the procedures recommended by Resolution no. 196/96 were followed.

Results

Participants monocularly estimated the depth or relief of polychrome and monochrome concave masks displayed in different positions and illumination conditions, in a total of 400 stimuli presentations. Table 1 presents the percentage frequencies of the responses indicating the face as concave (categories 1 e 2), flat (category 3) or convex (category 4 and 5) for the polychrome and monochrome concave masks illuminated from above, from below, and for the upside down concave mask illuminated from below. The majority of the observers attributed convexity to the concave mask: 75.0% when the concave polychrome mask was illuminated from above, 75.0% when illuminated from below, 72.5% illuminated from the right, 82.5% illuminated from the left, and 80.0% when presented upside down and illuminated from below. The concave monochrome mask was perceived as convex in 65.0% of the responses of the observers when it was illuminated from above, in 75.0% when illuminated from below, in 50.0% when illuminated from the right, in 67.5% from the left, and in 67.5% when the mask was presented upside down and illuminated from below.

A Repeated Measure Analysis of Variance (Anova) (2 colors x 5 illumination directions) was conducted for the depth and relief estimates for the hollow-face in centimeters, measured using a tape measure. The main effects of color $F(1, 39) = 0.98$ and direction of illumination $F(3, 136) = 2.15$; were not significant ($p>0.05$). There was also no significant interaction between color and direction of illumination $F(3, 111) = 0.29$; $p>0.05$.

Figure 1 shows the mean estimate and standard error for the depth perceived between the base of the face and the tip of the nose in the polychrome and monochrome masks in the upright position for the categories: totally concave (C1), partially concave (C2), flat (C3), partially convex

Table 1
Frequencies (%) of judgments of the concave mask as concave (categories 1 and 2), flat (category 3) and convex (categories 4 and 5) in different positions and illumination conditions

Illumination	Categories	Polychrome (%)	Monochrome (%)
From above/overhead	Concave	25.0	35.0
	Flat	0.0	0.0
	Convex	75.0	65.0
From below/underneath	Concave	20.0	20.0
	Flat	5.0	5.0
	Convex	75.0	75.0
From the right	Concave	22.5	42.5
	Flat	5.0	7.5
	Convex	72.5	50.0
From the left	Concave	17.5	32.5
	Flat	0.0	0.0
	Convex	82.5	67.5

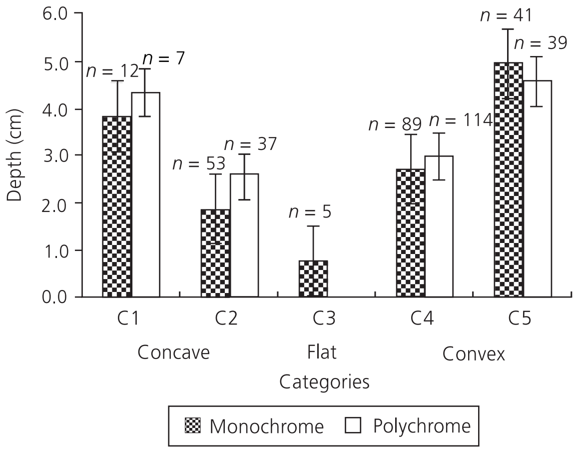

Figure 1. Concave Mask Judgments independent of source of illumination.

Note: Mean estimate and standard error in depth or relief perceived between the base of the face and the tip of the nose in polychrome and monochrome masks, for the categories: totally concave (C1), partially concave (C2), flat/plain (C3), partially convex (C4), and totally convex (C5), in 400 stimuli observations by 40 participants (*n* = frequency of responses by category).

(C4), and totally convex (C5). The frequency of the responses in each category allows the overall understanding of the relative frequencies in Table 1.

Figure 1 shows that, in both masks, the mean perceived depth ranged between 2 and 5 cm for convex and concave categories, close to the 3 cm physical concavity of the mask. However, it is important to note that even in situations in which the masks were classified as flat, some depth was still attributed to them.

Table 2 depicts the relative frequency of the judgments of the concave polychrome mask in the upright position illuminated from above and from below. When the concave polychrome mask was presented in the upright position and illuminated from above, 75.0% of the observers perceived it as convex. When the concave mask was presented in the upside down position and illuminated from below, convexity was perceived by 80.0% of the observers. In the conditions with the monochrome mask, the concave mask presented upright and illuminated from above was perceived as convex by 65.0% of the observers. When the concave mask was presented in the upside down position and illuminated from below, convexity was perceived by 67.5% of the observers.

To analyze the role of the orientation of the mask in depth judgments, Figure 2 and 3 graphically present the mean estimate and standard error of perceived depth or relief between the base of the face and the tip of the nose in the polychrome concave mask in the upright position and illuminated from overhead, as well as upside down and illuminated from below, respectively, according to the categories: totally concave (C1), partially concave (C2), flat (C3), partially convex (C4) and totally convex (C5).

Table 2
Frequencies (%) of judgments of the concave mask as concave (categories 1 and 2), flat (category 3) and convex (categories 4 and 5) in the positions: upright and illuminated from above, and upside down and illuminated from below

Position of the mask	Categoriy	Polychrome (%)	Monochrome (%)
Upright	Concave	25.0	35.0
	Flat	0.0	0.0
	Convex	75.0	65.0
Upside down	Concave	20.0	32.5
	Flat	0.0	0.0
	Convex	80.0	67.5

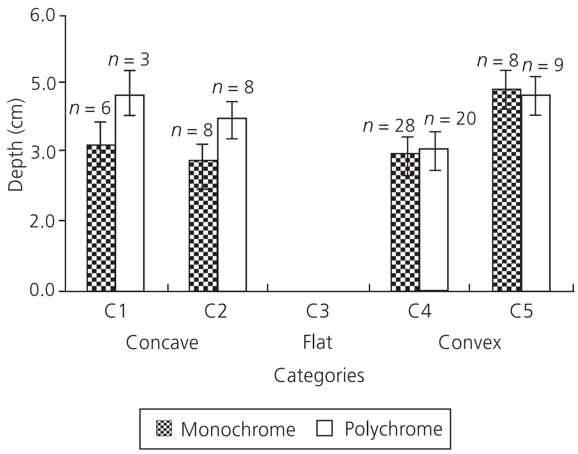

Figure 2. Upright concave mask illuminated from above.

Note: Mean estimate and standard error in depth or relief perceived between the base of the face and the tip of the nose in a concave mask in the upright position illuminated from above in the categories: totally concave (C1), partially concave (C2), flat/plain (C3), partially convex (C4), and totally convex (C5), in 80 stimuli observations by 40 participants (*n* = frequency of responses by category).

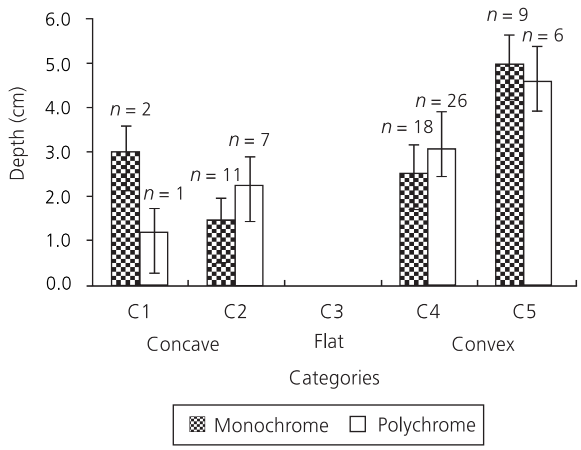

Figure 3. Upside down concave mask illuminated from below.

Note: Mean estimate and standard error in depth or relief perceived between the base of the face and the tip of the nose in a concave mask in the upside-down position illuminated from below in the categories: totally concave (C1), partially concave (C2), flat/plain (C3), partially convex (C4), and totally convex (C5), in 80 stimuli observations by 40 participants (*n* = frequency of responses by category).

Comparing the perception of depth or relief between the polychrome concave mask in the upright position illuminated from overhead and the upside down mask illuminated from below there is no evidence to suggest that the positioning affects the perception of depth or relief in the concave mask: $t(39) = 1.41$, $p=0.17$. There is also no evidence to suggest any differences among depth perception in the monochrome mask positioned upright or upside down and illuminated from above or below when observed monocularly: $t(39) = 1.46$, $p=0.15$. The statistical analyzes were performed using the Paired *t*-test. In summery, the analysis of the results suggests that the hollow-mask illusion is robust and virtually invariant to changes in mask color, orientation and lighting position.

Discussion

This study demonstrated the prevalence of the perception of convexities in concave objects, confirming previous studies (Hill & Bruce, 1994; Hill & Johnston, 2007; Langer & Bülthoff, 2001; Quaglia & Fukusima, 2009). The majority of the observers made the monocular inversion of depth, perceiving the concave mask as convex. According to Gregory (1997), the natural human propensity for visual depth reversal of concave faces occurs because the high-order, top-down processes superimpose the brain input, processes called low-order or bottom-up.

In the present study, the concave mask was observed monocularly and presented inside a box at a fixed distance from the observer. The observation hole reduced the information about the distance of the object. The color, the illumination and the positioning of the mask did not influence the categorical judgments of the mask as concave, flat or convex, nor the distribution of responses in those categories.

There were also no significant differences in depth perception between the different conditions of illumination source and mask color, when measured using the retractable measuring tape. Interestingly, some of the categorical judgments of the hollow mask as flat were followed by an attribution of centimeters with the measuring tape. There are two hypothetical explanations for this result (1) the observers could have been biased by the previous task in which they were asked whether the mask was concave, convex or flat; (2) faces are usually perceived as tridimensional, demonstrating the importance of top-down cognitive processes in visual perception.

The strength of the hollow-face illusion in relation to any changes in the mask position is noted in Table 2. There were no significant differences between the perceived depth in centimeters for the polychrome or monochrome masks presented in the upright position and illuminated from above and in the upside down position and illuminated from below. Quaglia and Fukusima (2009) highlighted the fact that the positioning of the concave mask, independent of its color, does not modify the perception of its depth and relief. Even though positioning of the mask and color are facilitator conditions for the monocular inversion of depth, they are not crucial to its perception. The results of this study support the findings from Quaglia and Fukusima (2009), demonstrating stability of the concave-convex inversion in the different variations of environmental stimuli corroborating the prevalence of higher-order over lower-order factors in this illusion.

Conclusion

The present study investigated the monocular perception of depth and relief in the hollow-face mask. Hollow masks of two different colors were observed inside a box, in two positions, and illuminated from different directions.

The majority of the observers made the monocular inversion of depth, perceiving the concave mask as convex. This result was independent of the conditions in which the stimuli were presented. The hollow-face illusion was shown to be a robust phenomenon, even when the mask was observed monocularly from inside a box. The perception of the concave mask as convex is a demonstration of how the top-down processes act on the sensorial, bottom-up processes.

In this study a box with an observation hole was used with a smaller sized mask and internal illumination. This instrument was designed to enable observations even in a reduced space.

The results of this study need to be compared with those obtained using other instruments to investigate both monocular and binocular depth perception. The current study presents a new contribution to studies in the field, as the observation box is a small, portable, useful, and inexpensive tool for studying visual phenomena.

References

Dima, D., Dietrich, D., Dillo, W., Emrich, H. M., & Hinderk, M. (2010). Impaired top-down process in schizophrenia: A DCM study of ERPs. *Neuroimage, 52*(3), 824-832.

Dima, D., Dillo, W., Bonnemann, C., Emrich, H. M., Detlef, E., & Dietrich, D. E. (2011). Reduced P 300 and P 600 amplitude in the hollow-mask illusion in patients with schizophrenia. *Psychiatry Research: Neuroimaging, 191*(2), 145-151.

Dima, D., Roiser, J. P., Dietrich, D. E., Bonnemann, C., Lanfermann, H., Emrich, H. M., & Dillo, W. (2009). Understanding why patients with schizophrenia do not perceive the hollow-mask illusion using dynamic causal modeling. *Neuroimage, 46*(4), 1180-1186.

Emrich, H. M., Weber, M. M., Wendl, A., Zihl, J., Von Meyer, L., & Hanisch, W. (1991). Reduced binocular depth inversion as an indicator of cannabis induced censorship impairment. *Pharmacology, Biochemistry and Behavior*, *40*(3), 689-690.

Gregory, R. L. (1997). Knowledge in perception and illusion. *Philosophical Transactions of the Royal Society B*: *Biological Sciences*, *352*(1358), 1121-1128.

Hill, H., & Bruce, V. (1993). Independent effects of lighting, orientation, and stereopsis on the hollow-face illusion. *Perception*, *22*(88), 887-897.

Hill, H., & Bruce, V. (1994). A comparison between the hollow-face and hollow-potato illusions. *Perception*, *23*(11), 1335-1337.

Hill, H., & Johnston, A. (2007). The hollow-face illusion: Object-specific knowledge, general assumptions or properties of stimulus? *Perception*, *36*(2), 199-223.

Kleffner, D., & Ramachandran, V. S. (1992). On the perception of shape from shading. *Perception & Psychophysics, 52*(1), 18-36.

Koethe, D., Kranaster, L., Hoyer, C., Gross, S., Neatby, M. A., Schultze-Lutter, F., … Leweke, F. M. (2009). Binocular depth inversion as a paradigm of reduced visual information processing in prodromal state, antipsychotic-naïve and treated schizophrenia. *European Archives of Psychiatry and Clinical Neuroscience, 259*(4), 195-2002.

Langer, M. S., & Bülthoff, H. H. (2001). A prior for global convexity in local shape-from-shading. *Perception*, *30*(4), 403-410.

Lent, R. (2005). *Cem bilhões de neurônios*: *conceitos fundamentais de neurociências*. São Paulo: Atheneu.

Leweke, F. M., Schneider, U., Radwan, M., Schmidt, E., & Emrich, H. M. (2000). Different effects of nabilone and cannabidiol on binocular depth inversion in man. *Pharmacology, Biochemistry and Behavior*, *66*(1), 175-181.

Liu, B., & Todd, J. T. (2004). Perceptual biases in the interpretation of 3D shape from shading. *Vision Research, 44*(18), 2135-2145.

Papathomas, T. V., & Bono, L. M. (2004). Experiments with a hollow mask and a reverspective: Top-down influences in the inversion effect for a 3-D stimuli. *Perception*, *33*(9), 1129-1138.

Quaglia, M. A. C., & Fukusima, S. S. (2009). Cor, iluminação e orientação do reverso de uma máscara facial não afetam a ilusão da máscara côncava. *Estudos de Psicologia*, *14*(2), 97-105.

Ramachandran, V. S. (1988). Perceiving shape from shading. *Scientific American*, *255*(2), 676-683.

Rossini, J. C., & Galera, C. (2006). A atenção visual: estudos comportamentais da seleção baseada no espaço e no objeto. *Estudos de Psicologia*, *11*(1), 79-86.

Schneider, U., Borsutzky, M., Seifert, J., Leweke, F. M., Huber, T. J., Rollnik, J. D., & Emrich, H. M. (2002). Reduced binocular depth inversion in schizophrenic patients. *Schizophrenia Research*, *53*(1), 101-108.

Schneider, U., Dietrich, D. E., Sternemann, U., Seeland, I., Gielsdorf, D., Huber, T. J., … Emrich, H. M. (1998). Reduced binocular depth inversion in patients with alcoholism. *Alcohol & Alcoholism, 33*(2), 168-172.

Schneider, U., Leweke, F. M., Niemcyzk, W., Sternemann, U., Bevilacqua, M., & Emrich, H. M. (1996a). Impaired binocular depth inversion in patients with alcohol withdrawal. *Journal of Psychiatric Research*, *30*(6), 469-474.

Schneider, U., Leweke, F. M., Sternemann, U., Weber M. M., & Emrich, H. M. (1996b). Visual 3D illusion: A systems-theoretical approach to psychosis. *European Archives of Psychiatry & Clinical Neuroscience*, *246*(5), 256-260.

Semple, D. M., Ramsden, F., & McIntosh, M. (2003). Reduced binocular depth inversion in regular cannabis users. *Pharmacology, Biochemistry and Behavior*, *75*(44), 789-793.

Sternemann, U., Schneider, U., Leweke, F. M., Bevilacqua, C. M., Dietrich, D. E., & Emrich, H. M. (1997). Propsychotische veränderung der binokulären tiefeninversion durch schlafentzug. *Der Nervenarzt*, *68*(7), 593-596.

Sternberg, R. J. (2008). *Psicologia cognitiva* (4ª ed.). Porto Alegre: Artmed.

Yoshida, H. (2006). The effects of facial texture, stimulus orientation and light direction on the hollow-face illusion. *Bulletin of the Graduate School of Education, Hiroshima University*: *Part.III, Education and Human Science*, *55*, 321-329.

Received on: 12/5/2012
Final version on: 9/10/2013
Approved on: 10/18/2013