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GENERAL ARTICLE

Subliminal perception of complex visual stimuli

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Abstract
Rationale: Unconscious perception of various sensory modalities is an active subject of research though its function and effect on behavior is uncertain.
Objective: The present study tried to assess if unconscious visual perception could occur with more complex visual stimuli than previously utilized.
Methods and Results: Videos containing slideshows of indifferent complex images with interspersed frames of interest of various durations were presented to 24 healthy volunteers. The perception of the stimulus was evaluated with a forced-choice questionnaire while awareness was quantified by self-assessment with a modified awareness scale annexed to each question with 4 categories of awareness.
At values of 16.66 ms of stimulus duration, conscious awareness was not possible and answers regarding the stimulus were random. At 50 ms, nonrandom answers were coupled with no self-reported awareness suggesting unconscious perception of the stimulus. At larger durations of stimulus presentation, significantly correct answers were coupled with a certain conscious awareness.
Discussion: At values of 50 ms, unconscious perception is possible even with complex visual stimuli. Further studies are recommended with a focus on a range of interest of stimulus duration between 50 to 16.66 ms.
Keywords: subliminal perception, visual stimuli, complex stimuli

Introduction

The field of subliminal and unconscious perception of visual and other sensory modalities has been an active subject of research since Sidis described a series of experiments in his work The Psychology of Suggestion. New York, 1898, in which he postulated the existence of the presence within us of a secondary sub-waking self that perceives things which the primary waking self is unable to get at. In one of the experiments he described, five figures and five letters were written "in faint outline" on ten cards which were presented to eight subjects with normal vision at such a distance that the character was outside his range of vision, he saw nothing but a mere dot, blurred and often disappearing altogether. Each time a card was presented the subject was required to give some particular name of the character he took that dot to be. The results he obtained from his series of experiments showed nonrandomness in the subjects' guesses, which led him to a theory of unconscious cerebration in which physiological processes are not strong enough to rise above the threshold of consciousness. In short, each figure stimulated the peripheral sense organ, giving rise to a central but unconscious physiological process. Now, according to the theory of unconscious cerebration, it was this unconscious physiological process that helped the subject to form correct guesses [**1**].

Unconscious perception has been studied in other approaches as well, such as that of Lazarus and McCleary [**2**], which used galvanic skin response (GSR) as the basis for an objective measure of perception. In this study, ten nonsense syllables were presented to subjects, of which five syllables were paired with an electrical shock. After the initial conditioning, the ten syllables were presented tachistoscopically to hinder their conscious discrimination. In this condition, GSR was shown to be of greater magnitude following syllables previously paired with the electrical shock independent of the identification of the respective syllable. Having assumed GSR is mediated autonomically and sensitive to both conscious and unconscious perceptual processes, the investigators concluded that this result is in accordance with unconscious perception [**3**].

Further experimentation utilized visual target masked priming [**4,5**] and Stroop color-word interference tasks [**6**] to investigate interference of stimulus identification following priming with various masking conditions. In such experiments, Marcel [**4**] revealed significant decision time interference through priming even when subjects reported no awareness of the presence of a prime in the subthreshold experimental sessions, the subjects assuming these to be control sessions with no prime used.

The current research in the field of subliminal perception by using peripheral visual target stimuli (small circular patches) rendered subliminal by a contrast modulation on a background of a pattern of random white noise, showing that visual subliminal stimuli elicit an increase in the alpha-band power as measured with electroencephalography [**7**]. Further research has demonstrated the supraliminal peripheral vision target detection to be impaired when embedded in a concurrent train of subliminal stimuli presented at the same location. It has been proposed that this effect is due to an inhibition response to low-contrast subliminal stimuli that protect the cortex from visual noise [**8**]. A similar mechanism has been previously shown to exist in the somatosensory cortex [**9**].

Imaging studies have shown a different cortical activation pattern in subliminal versus supraliminal perception through functional magnetic resonance imaging by utilizing several sensory modalities including visual stimulation. A predominance of right fusiform gyrus, right caudal anterior cingulate cortex and right insula activation has been shown in subliminal stimuli presentation versus the presentation of supraliminal stimuli in which left rostral anterior cingulate cortex activation predominated [**10**].

Further evidence on the field of subliminal perception and influence on behavior continues to be produced as a recent study has found consistent evidence of learning of serial orders of visual symbols even when participants could not detect the stimuli [**11**].

The present study tried to investigate whether the detection of stimuli in the absence of self-reported awareness could occur with more complex visual stimuli than previously utilized, to better asses real-world influence of such mechanisms or if such an effect is restricted to more simple stimuli (simple geometric shapes, color-word associations) as thoroughly documented in the available literature.

Materials and Methods

The experiment was performed on 24 healthy adult volunteers, participants in the 2014 Brain Awareness Week conferences. The experimental group contained 16 females and 8 males with the mean age of 24 years (minimum age of 19 and maximum of 44 years). An informed consent was obtained from all the participants beforehand with a brief description of what was required and the importance of guessing even when consciously no stimulus was perceived.

The experiment consisted of the presentation of 3 clusters each containing 10 videos. The video content was a slideshow of 5 complex images (color photographs of various animals) each shown for a duration of 3 seconds and an interspersed complex image belonging to a different semantic category (color photograph of a fruit) shown for a duration between 16.66 to 200 milliseconds. The fruits in each cluster were chosen to be of different color (example banana, strawberry, orange, and apple) to maximize the possibility of a correct selection if perceived and minimize the ambiguity that might have appeared between the fruits of the same color. The location of the frame of interest was randomized among the indifferent images to minimize the expectancy of the stimulus but never being the first or the last image shown. Randomization was performed by using a string of random numbers generated by a true random number service based on atmospheric noise (http://www.random.org [**12**]). The color photographs utilized for the experiment were high-resolution royalty free stock images of various animals and fruits [**13**].

The videos were built in Sony Vegas Pro 11 (build 682) and were shown in MPEG-2 format 720x576 pixels (standard PAL resolution), 16:9 aspect ratio, with a frame rate of 60 fps, with a constant bit rate of 9,800,000 bps. Standard PAL resolution of 720x576 pixels was chosen as this was the standard television format utilized in the region and this was the resolution which participants were most accustomed to. The frame rate was chosen because of the inherent limitation of a maximum 60 Hz refresh rate of the projector (Panasonic PT-LB90NT Portable LCD Projector) used for the presentation of the videos. The image of interest was presented for the duration of 1 frame (16.66 ms), 2 frames (33.33 ms), 3 frames (50 ms), 4 frames (66.66 ms), 5 frames (83.33 ms), 6 frames (100 ms), 7 frames (116.66 ms), 9 frames (150 ms) or 12 frames (200 ms), also one video contained no interspersed frame to act as a control. Each video contained varied indifferent stimuli (different color photographs of animals) and varied frames of interest and for each selected duration, 3 videos were presented totaling 30 videos. Among the clusters to minimize the possibility of a learning effect, the videos were presented in a random order, the randomization being performed with a different true random number string as above [**12**].

The perception of the frame of interest was evaluated after the presentation of each video, with a forced-choice questionnaire containing 4 choices of fruit and annexed to each question a 4-category self-assessment of awareness of the stimulus, modified from the scale created by Zeki and Ffytche [**14**], which was used in evaluating the awareness in blindsight patients as presented in **Table 1.**

Responses of perceived stimulus (correct fruit) were graded as true or false. Collected responses to each category of awareness and corresponding stimulus duration were analyzed by using Small Stata 12.1 (StataCorp LP) with the binomial probability test with an expected k value of .25.

Table 1. Awareness scale modified from Zeki and Ffytche [**14**]

Response	Details	Score
Unaware	I did not see anything. I am entirely guessing	0
Aware	I have a feeling there was something there and I am trying to guess what	1
	I am reasonably sure of what I saw	2
	I am sure of what I saw	3

Results

The absolute number of responses in each category of perception and corresponding awareness scores are presented in **Table 2.**

Table 2. Absolute number of responses in each category of stimulus duration

Awareness	16.66 ms	33.33 ms	50 ms	66,66 ms	83,33 ms	100 ms	116,66 ms	150 ms	200 ms
Score 0	42	2	26	36	10	0	0	1	6
Score 1	28	15	28	10	6	4	1	1	1
Score 2	2	31	13	2	11	10	3	1	2
Score 3	0	24	5	24	45	58	68	69	63

From the absolute number of responses at each stimulus duration as could be expected at higher lengths of presentation of the frame of interest, from 200 to 116.66 ms (corresponding to 12 to 7 frames displayed at 60 Hz), almost all responses were of certainty of awareness (type of response of "I am sure of what I saw). To these types of responses and at these durations, the percentage of correct responses ranged from .95 to 1 all highly significant ($p < .00001$). The percentages of correct responses are presented in **Table 3.**

There was an approximately linear decrease in the number of responses corresponding to the certainty of awareness from 100 to 50 ms (corresponding to 6 to 3 frames displayed at 60 Hz). Even though the number of responses of certainty decreased, the percentage of correct responses of those who were aware of the frame of interest remained high, at 50 ms (p value of .00097). The correspondence of correctly perceived stimulus and certain conscious awareness of stimuli continued even at 30 ms display duration ($p < 0.0001$).

The other categories of awareness responses gradually increased as the frame of interest display time decreased. The subjects' unawareness responses (type of response: I did not see anything. I am entirely guessing) started to increase from 83.3 to 16.66 ms with a dip at 33.33 ms.

At 50 ms display time of the frame of interest, 26 out of 72 answers were of unawareness of any stimuli presented but the percentage of correct responses of this particular category was . 53 reaching a statistical significance (p value of 0.002). Binomial test results are presented in **Table 4**.

At 16.66 ms, the majority of responses were of unawareness or of partial conscious awareness of stimuli but forced-choice responses did not reach a statistical significance, exhibiting randomness of answers.

Table 3. Percentage of correct responses in each category of stimulus duration

Awareness	16.66 ms	33.33 ms	50 ms	66,66 ms	83,33 ms	100 ms	116,66 ms	150 ms	200 ms
Score 0	0.1428	0	0.5384	0.3888	0.5	insufficient observations	insufficient observations	0	0.5
Score 1	0.2142	0.6	0.4642	0	0.5	0.25	0	1	0
Score 2	0	0.6774	0.6923	0.5	0.9090	0.7	1	1	1
Score 3	insufficient observations	0.9166	1	0.9583	1	0.9655	0.9558	1	1

Table 4. Binomial test p-value (values under .05 marked in blue)

Awareness	16.66 ms	33.33 ms	50 ms	66,66 ms	83,33 ms	100 ms	116,66 ms	150 ms	200 ms
Score 0	0.1518	1	0.002	0.0802	0.1344	insufficient observations	insufficient observations	0.25	0.1694
Score 1	0.8281	0.0041	0.0145	0.076	0.1694	1	1	0.25	1
Score 2	1	0.000001	0.0009	0.4375	0.000008	0.003	0.0156	0.25	0.0625
Score 3	insufficient observations	0	0.0009	0	0	0	0	0	0

Discussion

The results of the present study supported certain conclusions.

At 16.66 ms, the correct perception of static complex imagery interspersed among other indifferent images belonging to a different semantic category was not possible and the majority of subjects reported no conscious awareness of any stimulus being interspersed among the presented images.

At 50 ms, a subgroup of subjects reported no conscious awareness of the presented stimuli but responses were statistically significant different from random. The coupling of nonrandom answers and no self-reported awareness of the stimulus suggested that an unconscious perception is possible even with more complex visual stimuli than previously utilized to detect a threshold for unconscious perception. Although at 33.33 ms, 24 responses corresponded to certain conscious awareness and were significantly different from random, it is possible that in the present experiment subjects belonged to two (or more) different groups of threshold of perception. One group with a high threshold for perception, allowed the correct perception of fast stimuli of 33.33 ms., and, a second group of subjects with a low threshold for perception, had a limit of conscious perception at 50 ms. This study did not address the difference between these two presumed cohorts, whether it resided in the attention during experimentation, or in a true difference in the threshold for the perception of complex stimuli.

The limits of the present study resided in a small sample of subjects and large increments in durations of frames of interest limited by the equipment employed for experimentation. Technical difficulties were also experienced during the experiment (glitching of two undetermined videos during experimentation), which might have also been attributed to the dip in the responses of unawareness at 33 ms stimulus duration.

The results of the present study recommend future studies with smaller increments of stimulus duration to better quantify awareness and perception of complex stimuli with a focus on a region of interest of the threshold of perception between 50 and 16 ms.

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Disclosures

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