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Exploring relationship between attention and consciousness using Dual-Task paradigm

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ABSTRACT

The ongoing debate on distinctiveness of attention and consciousness form decades claims that some form of awareness exist even in absence of attention. To testify this claim dual-task paradigm has been recreated for independent manipulation of top-down attention and awareness. While the subject are engaged in an attentional demanding central letter task, for awareness periphery task consisting gist of the natural scene, animal image and gender were presented for discrimination for less than 100ms. The subject performed in both single-task and dual-task conditions. After an adequate amount of training, stimulus onset asynchrony (SOA) was determined for all subjects individually. After final testing we can conclude that attention and consciousness are distinct phenomena. Subject could discriminate natural scene and animal images both in coloured and greyscale with performance as high as 90% correct judgement, while in gender discrimination the performance was moderately low around 70-80%.

Keywords: attention; consciousness; Dual-task; independent mechanism

1. Introduction

The relationship between attention and consciousness is into debate from more than a decade now, various scholars have attempted to resolve the need and sufficiency of awareness for attention (Baars, 1999; Braun, 2003; Fei-fei, Koch, & Perona, 2005; Koch & Tsuchiya, 2007; Reddy, Moradi, & Koch, 2007; Reddy, Reddy, & Koch, 2006; Tsuchiya, Block, & Koch, 2012; Vanrullen, Reddy, & Koch, 2004). Contemporary views believed our visual functions are very wide (categorization, distinction, recognition, etc.) underlying feature integration no function is possible without some level of attentional resources (de Brigard & Prinz, 2010; Cohen, Cavanagh, Chun, & Nakayama, 2012; Mack, 2003; O' Regan & Noë, 2001; Rensink, 2009). Various scientific analogies have been put forward to settle the debate; the most recent leap in the opposite direction towards evolution perspective has been put forward (Haladjian & Montemayor, 2015). It explained that most of the cognitive psychologist would agree attention is an early adaptation of humans to select and filter incoming information's while conscious must be a late adaptation with increasing complexity so some form of distinction between the two processes can be based on our system formation itself.

Amidst the view of such tight entanglement between the two, they cannot be independently manipulated easily (Braun & Julesz, 1998). Dual-task paradigm enable to manipulate subjects top-down attention in the central task and awareness through the peripheral stimulus presented. Awareness and attention both are multifaceted in functional capacity; fully functional dissociability is a challenge while distinctions in certain aspects of image processing have been found through various experimental paradigms. Extensive study in this area has already been conducted showing dissociative relation, even in blindsight attentional performance was not synonymous with awareness for it (Eimer & Grubert, 2015; Kentridge, Heywood, & Weiskrantz, 1999, 2004; Koch, 2013; Tsuchiya & Koch, 2009).

Natural images have been scrutinized at various aspects with the concept of it as being pre-attentive in nature. Mack (2003) experimentally showed how natural scene is immune to inattentional blindness. Cohen, Alvarez, & Nakayama (2011) on the contrary implied natural scene just as a highly efficient and thus could be categorized in dual-task interference in less than 150ms, which is too short a span for focused attention to play a role (Bierdrmam, 1972). In an attempt to verify the distinctiveness spatial attention from awareness, various other stimuli have been examined. Genders, famous and non-famous faces discrimination (Reddy et al., 2006), direct and averted gaze (Yokoyama, Sakai, Noguchi, & Kita, 2014), various artificial and geometric variances such as bisected disc (Li, Vanrullen, Koch, & Perona, 2002), etc. (Fei-fei et al., 2005) said that in comparison to natural images synthetic stimuli are less efficient in categorization. According to Triesman's feature integration vivid features such as colours, shape, dimensions and others are

responsible, natural stimulus provides wider dimensional space while categorizing so the possibility of break down is few while artificial objects get constricted. Thus in this study, we try to analyze the phenomena of attention and consciousness in light of dual-task paradigm taking both natural scenes offering border space in colourful and greyscale and averaged male and female images offering constricted dimension.

1.1 Hypothesis

a. The performance in central task will be low in dual condition than single condition.
b. The performance of peripheral task will be low in dual-task condition.
c. The performance of central and peripheral task will be high in both single and dual-task condition.

2. METHOD

2.1 Participants

A total of five naïve subjects, including both male and female, were taken for the study, all were research scholars of Banaras Hindu University Varanasi. The age for subject ranged from 25-30 years with mean age of 26.8 years. All subjects gave their informed consent to voluntary participate in the experiment and all reported normal or corrected to normal visual acuity. They were made to perform in all three different experimental conditions after adequate training - each participant devoted near about 10-12 hours each to complete the whole processes.

2.2 Inclusion criteria

- Should be normal with no history of any psychiatric illness.
- Should have normal or corrected to normal vision, and no colour blindness.
- A basic level of education with computer familiarity was important in order to perform the task.

2.3 Exclusion criteria

- Participants who have already performed any cognitive task remotely related was excluded.
- Participants who were not able to respond using both hands simultaneously even after training were not called for final testing phase.

2.4 *Tools*

A display screen of Dell 15.6 inches with a screen resolution of 1388*768 pixel was used to display the task to the subjects, the refresh rate of the screen was set at 65Hz. For designing of Experiment SuperLab 4.5 software was used. Each participant was made comfortable and seated nearly 65cm away from the screen in Lab situation. Subjects had to use both mouse and keyboard to respond.

For the stimuli images was taken from two database four different sets of animals was used consisting of deer, horse, rabbit and tiger covering broad dimensions was taken from IAPS International Affective Picture system (Lang, Bradley, & Cuthbert, 2008). And for natural scene also four sets of images was used covering wide dimension of landscape field, garden, beach and sea from IAPS. For masking these images the pixel distortion was used, the pixel was increased more than 50% and also puzzled to prevent any recognition from the original. Another database was used for an averaged male and female figure from the University of Regensburg, Germany.

3. Procedure

After subjects arrived in the lab, all necessary actions like inform consent, briefing about the whole experimental process and instructions were given. Demographic sheets were handed to acquire details about inclusion and exclusion criteria's. The experimental task had three variations with same central letter task in all but different sets of peripheral task as enumerated below.

3.1 Experiment 1

A different set of the same category of images, i.e., natural and animal image was used differing from that of training sessions was presented along with the central letter discrimination (Figure 1). Before the beginning of the trial, subjects were made to familiarize with the images on average of the 30s per picture. Here subjects were instructed about which image is a target (animal) and which is not (natural scene), equal trials of both target and non-target were given and stimulus onset asynchrony (SOA) for each subject for peripheral was determined individually while letters were present for 250ms. This individual allocation of SOA (i.e., time of presentation of one even was important as this task required an high motor coordination of both hand which differed from subject to subject. The subject performs three blocks in a single condition and four in dual condition on consecutive days. In dual-task condition more

number of trails were taken because of excessive demand of motor coordination some trails could go blank, adhering to failure to press the key or pressing the key to faint that it failed to get registered.

3.2 Experiment 2

In this set with central letter task, greyscale images natural scene and animal images were presented in the periphery as shown in figure1. Four set of images were used with the proportion of Red 10%, Green 60 %, and blue 30%. The images similar as in training but the only colour scale was changed to see the effect of colour in near absence of attention. In this subject performed three blocks for single condition and four for dual condition. All 5 subjects performed in this task on consecutive days.

3.3 Experiment 3

In this set Gender discrimination task was given in the periphery with same central letter task. An averaged male and female image was presented across 52 trails with an equal number of male and female images. The image was average (i.e. very similar looking shown in figure 1) so familiarizing time was a bit longer in this trial and was in between 30-45s. Target was female for male subjects and vice versa so subject had to press the mouse only when they see the target.

Three whole blocks for single and four for dual was given to all five subjects. The procedure for central and peripheral task has been detailed as follow.

3.4 Central Letter task

The dual-task paradigm was used to test the effects of attentional manipulation on peripheral categorization performance. Each trial began with a white fixation cross presented on a black screen for 300 ± 100 ms before the onset of the stimulus. After at 0ms, five randomly rotated letters (Ts and Ls, either all the same (T) or one different from the other four (L)) were presented at the centre of the screen. The letters were rotated at 1.2 degrees from fixation. On this task, subjects reported if all five letters were identical or not by pressing one of two keys “S” when all the letters were identical and “D” when different as assign on the keyboard. The letters were each masked by a rotated letter F in the same rotation. The average presentation time for the letters was 200-250ms, which was stabilized after training and subject were given 3 blocks consisting of 52 trials in each session.

3.5 Peripheral discrimination task

Stimulus in the periphery was presented approximately 2.5 degrees of visual angle from the centre at a random location on the screen inside an imaginary rectangle at random possible location along with the screen against the black background. After the stimulus was presented, it was masked with 50% increased pixel and puzzled images. The peripheral mask always appeared before the central letter-masks. Stimulus onset asynchrony for individual subjects were determined based on training ranged from 76ms-130ms. A block consisting of 54 trials with 27 target and 27 non-target trials, a total of 3 blocks in each session was given and subjects responded by releasing the mouse key button as fast as they could, as releasing response is faster than pressing.

3.6 Dual task

In the dual-task condition, subjects had to perform both the central letter discrimination task and the peripheral identification task together by responding from one hand to central task (key S and D) and other to a peripheral task (releasing left mouse key) while fixating the eyes to the centre of the screen. In this experiment, subjects performed at least four blocks, and three blocks each of the central and peripheral tasks.

3.7 Training

The entire training procedure typically lasted between 5 and 6 hours on consecutive days for each five subjects. At the beginning of training, the letters were displayed for 500 ms and the animals for 173 ms before the masks appeared. During training, for each subject, the SOAs were decreased independently for both tasks when performance on a 52-trial block exceeded 90%. The training was complete when subjects' ''letter'' SOA had stabilized below 250ms, and peripheral SOA was kept as lowest possible depending on the performance of individual subjects ranging in between 76 to 130ms.

Normalized dual-task performance values were calculated by the method of simple linear scaling of the mean value of all five subjects individually for all three experimental variations. The scaling was graphed with mean of single-task performance to 100%, leaving chance at 50%. Normalized performance formula used was adopted from Bayesian equation by Fei Fei Li (2005) = 0.5 + 0.5[(P2 – 0.5)/ (P1 -0.5)]. The normalized data of all the participants in each of the experimental variation are depicted in Figure 5, 5a: Experiment 1 (Natural vs Animal images), 5b: Experiment 2 (Grey Scale), 5c: Experiment 3 (Male vs Female).

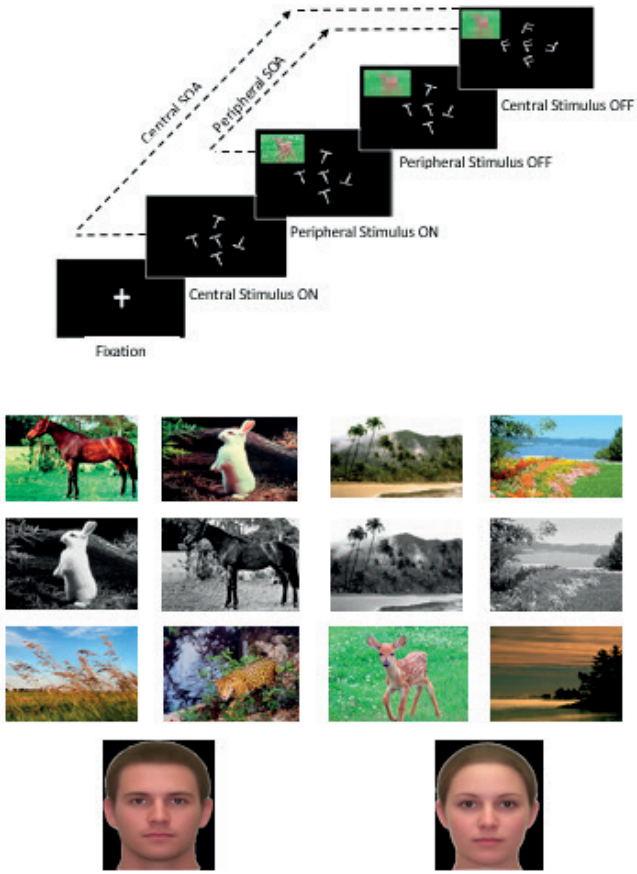

Figure 1. This is representation of experimental procedure and images used

4. Results

These series of experiment based on dual-task paradigm purports to see the need or necessity of attentional resources for awareness (Van Boxtel, Tsuchiya, & Koch, 2010). The focus of attention was manipulated by demanding central letter discrimination task and awareness through peripheral discrimination by altering qualities of stimulus presented in colour, nature, and dimensions.

The aim of the experiment was very simple if subjects peripheral responses were not hampered in parallel to the attention-demanding task then obviously awareness is independent if attention (Braun & Julesz, 1998). During the training session, each subject was trained on the natural and animal scene, after training was finished the final experiments were given.

In experiment 1 different set of the same category image i.e. natural and animal images was used. Across all the blocks average performance computed in single and dual-task condition in letter categorization (central task) was 94.44% and 91.66% respectively, t-test results were not significant i.e., no difference in performance was observed in single central with ($M= 90.73$, $SD= 2.87$) and dual central with ($M= 89.00$, $SD= 3.15$); $t(5) = 1.320$, $p > 0.05$. While in the peripheral task the performance ranged from 88.19 % in single condition and 86.44 % in dual condition, t-test results had a significant relationship in this case there was difference in performance in peripheral task in single condition ($M = 87.77$, $SD = 1.35$) and dual condition ($M= 82.13$, $SD = 2.84$); $t(5) = 4.864$, $p < 0.05$. The performance in the dual-task condition was moderately hampered in this experimental variation.

In Figure 2 the graph shows the plotting of individual performance of all five subjects. It clearly shows that performance of each subject in single as well as dual condition was more than 80% in each blocks, and no drastic deterioration of performance in dual-task condition.

In the second set of the experiment, the same image which was used in training was presented but in a standard greyscale, as we attempt to understand the crucial role of colour in awareness. The average performance of all the subjects on central task was 95.81% in single and 93.26% in dual-task condition, the t-test results of all the subjects show there was no significant difference in performance in single conditions with ($M= 89.99$, $SD= 4.82$) and in dual condition ($M = 88.34$, $SD = 3.58$); $t(5) = 1.010$, $p > 0.05$. Average peripheral performance where subject had to respond when animal image in greyscale appeared ranged from 91.66% and 94.78% in single and dual condition respectively, t-test results in peripheral performance also shows a non-significant difference with ($M = 91.08$, $SD = 3.62$) in single-task condition and ($M= 86.49$, $SD = 8.16$) in dual-task condition, $t(5) = 1.355$, $p > 0.05$. There was no decrease in performance, in both condition was observed as

shown in Figure 3, the subject could discriminate between grey animals and a natural scene in parallel with the letter "T" and "L" discrimination.

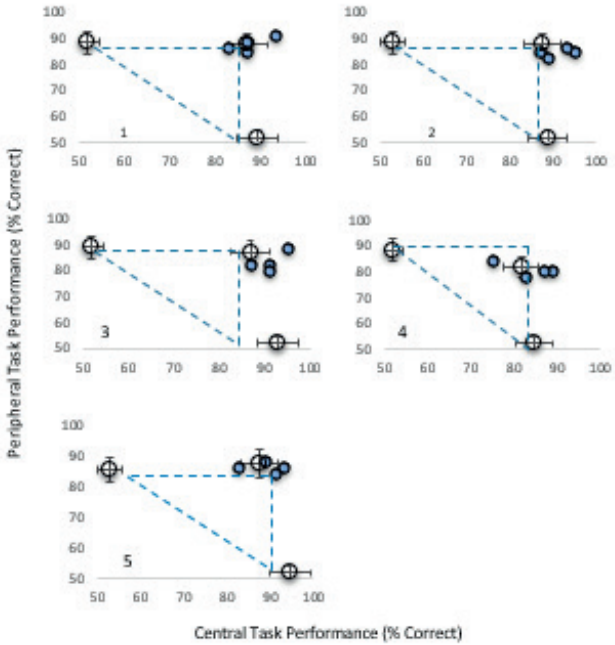

Figure 2. Performance of 5 subjects individually in experiment 1 depicted. Horizontal axis represents performance on the central letter discrimination task and vertical axis represents performance on peripheral identification task. Each filled circle is the participant's mean performance in the dual-task in one block, while an open circle represents mean performance over all blocks in the three experimental conditions: single central task, single peripheral task and the dual-task

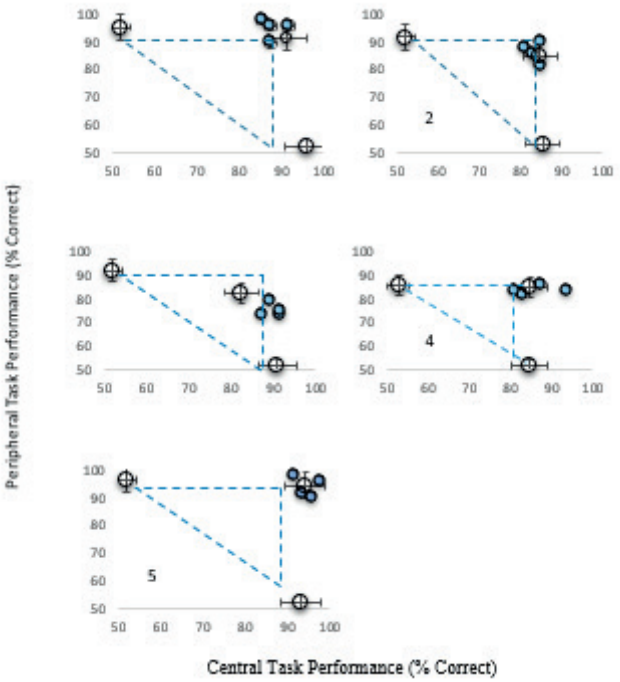

Figure 3. Performance of 5 subjects individually in experiment 2 depicted. Horizontal axis represents performance on the central letter discrimination task and vertical axis represents performance on peripheral identification task (Grey scale images). Each filled circle is the participant's mean performance in the dual-task in one block, while an open circle represents mean performance over all blocks in the three experimental conditions: single central task, single peripheral task and the dual-task

In final experiment 3, averaged faces of both genders were presented in the periphery. Gender discrimination involves more intricate information consisting of both global structure of the face and minute structures like eyebrows, lips, eyes, nose, etc. On averaging the correct responses in all the blocks we got score ranging 89.58 % for central task in single condition and 87.41% in dual condition, t-test results showed there is no significant difference in performance of letter task in single condition (M=86.09, SD=3.10) and dual condition (M= 83.26, SD = 3.32) t (5) = 1.825; p >

0.05. On the other hand scores for peripheral in single condition was 85.41 and dual was 81.76 while the t-test result was also non-significant in this case showing no difference in performance in single (M = 82.77, SD = 2.92) and dual condition (M = 8.14, SD = 1.19); t (5) = 2.815; p > 0.05.Thus subjects could say the difference between male and female image while engaged in an attentional demanding task. Figure 4 graph very well shows that each block performance and average performance of all group are all above 80%, which is a quite good performance.

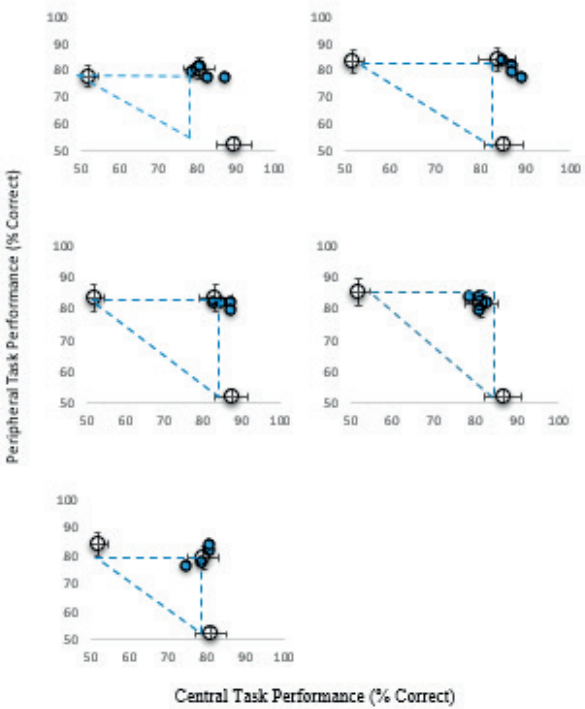

Figure 4. Performance of 5 subjects individually in experiment 3 depicted. Horizontal axis represents performance on the central letter discrimination task and vertical axis represents performance on peripheral identification task (Faces). Each filled circle is the participant's mean performance in the dual-task in one block, while an open circle represents mean performance over all blocks in the three experimental conditions: single central task, single peripheral task and the dual-task

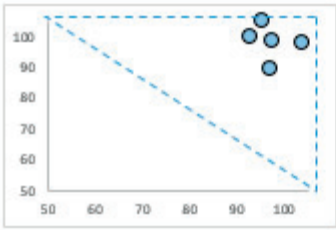

Figure 5a: *Normalized score of experiment 1*

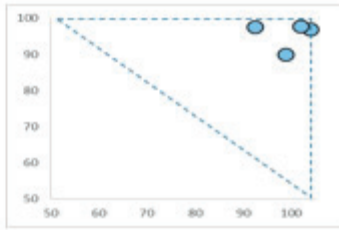

Figure 5b: *Normalized score of experiment 2*

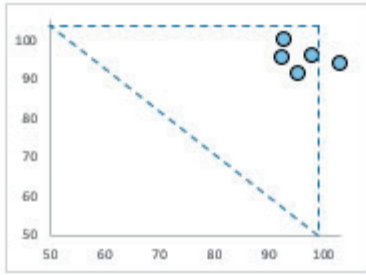

Figure 5c: *Normalized score of experiment 3*

Figure 5. This graph shows normalized performance graph of all five subjects (Each circle represents subject) in all three experiments. The horizontal axis represents central task and vertical peripheral task. Normalized performance values shown in >90% for all subjects. Normalized score is calculated by a simple linear scaling of the mean value of each participant's performance. The scaling mapped the mean single-task performance to 100%, leaving chance at 50%.Formula =0.5[(pd-0.5)\ps – 0.5)] +0.5

5. Discussion

Our findings comply with the earlier finding on the independent mechanism of consciousness in near absence of attention (Bussche, Hughes, Humbeeck, & Reynvoet, 2010; Koch & Tsuchiya, 2007; Li et al., 2002; Reddy et al., 2006). Not only behavioural finding but also various physiological evidence shows there underlie separate neural mechanisms (Dehaene & Naccache, 2001; Eimer & Grubert, 2014; Hsu, George, Wyart, & Tallon-baudry, 2011; Kentridge et al., 2004; Reddy et al., 2007; O' Regan & Noë, 2001; Tallon-Baudry, 2012). PPN (pre-frontal parietal network) has been identified as centre for both attention and consciousness and thus potential neural correlates has been identified earlier, PPN is also related to major cognitive functions like working memory, executive and orientation attention and consciousness forms the core of it. On contrary recent research shows how a "cumulative decision model" is confused with being dependent, the neural pathways for both attention and consciousness travels different neural pathways to same goal Tallon-Baudry, (2011). EEG studies of P300 pathways on sedated and normal participants also showed a clear dissociation as participants showed attentional activates sooner as they start responding behaviourally and awareness came after that (Chennu & Bekinschtein, 2012).

Cohen and colleagues (2012) claims that several high-level processing can occur without attention maybe because some stimuli like natural scene summons a very limited attentional resource, this would imply that performance in demanding attentional task should be at least be partly affected in dual-task condition but our finding shows that letter discrimination task was almost equally efficiently performed in all the experimental variation in both conditions. In experiment 1 where naïve stimulus of animal and natural scene were presented to the subjects different than ones which was used in training, in this set their peripheral performance was moderately affected giving us a significant result. Thus here our second hypothesis is accepted stating performance of periphery will be low in dual-task condition. This lowering of performance may be attributed to other factors like habituation to images from week-long training, difficult motor coordination required to respond using both hands and task fatigue etc. rather than challenges of awareness resources, the performance was not drastically affected and was above chance level for all subjects. Thus giving fair chances before calling it dependent mechanism. Li and colleagues (2002) has pointed out that particularly natural scene are robust to our perception and can be perceived with a minimal attentional requirement in comparison to the artificial geometric objects. In experiment conducted by Vanrullen, Reddy, and Koch (2004), we see a clear natural vs animal scene dissociation which has been argued being pre-attentive in nature and so we

used greyscale in experiment 2 subjects could discriminate eliminating colour hint. The result showed a non-significant difference in performance in single and dual condition clearly stating independent element of attention and awareness. Thus our third hypothesis is accepted, as no difference of performance was found in However, this human's ability to identify natural scene is so efficient because of the exposure throughout evolution our visual system is far much encountered with the natural scene than geometric shapes. Not only while gist visual display independence in attention and awareness is observed but also while pop-out visual display where the target is displayed among various homogeneous distractors which is even much more information to be processed without attaining focus of attention (Hsieh, Colas, & Kanwisher, 2011).

A special cortical area in fusiform gyrus exists for facial perceptions which involve qualitative computation to recognize faces in "Holistic" or "Global" manner as compared to another kind of stimulus (Kanwisher, Mcdermott, & Chun, 1997). As human brain expertise in face discriminations, it is one of the strong abilities we possess and so identifying male and female faces when they are averaged so that at glace they share similar characteristics like colour of skin, facial features, shape, eye gaze etc. discrimination was possible in experiment 3. While comparing performance across all the experiments in single and dual-task conditions the central performance was roughly equal and after the experiment in verbal report subjects reported that they could discriminate while focusing on the central task almost all the time but dual response pattern involving motor action lead them to miss pressing key few times.

Mostly stimulus quality is a trade-off with attentional resources to determine whether perception occurs with or without awareness and with or without attention. Merikle, Smilek and Eastwood (2001) said perception with and without awareness and perception with and without attention are equivalent ways of describing the same underlying process distinction. More empirical studies are needed yet to claim this statement fully. Thou at this stage a complete dissociation between the two cannot be inferred, a small sample size serve as a major limitation here. But on the ground level, we can begin to work in the direction knowing that partially these processes apply at different functional levels.

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