

The Impact of Gender Differences on Two-and Three-Dimensional Object Recognition: A Behavior and Event-Related Potentials Study

B. Y. Liu¹, Y. C. Lin², and C. J. Liu^{1*}

¹ Graduate Institute of Science Education, National Kaohsiung Normal University, Taiwan

² Elementary school teacher of Tainan City, Taiwan

Abstract-- Teaching with virtual 2D and 3D figures from computer techniques is a trend since visualized teaching materials can effectively deliver curriculum contents to students. However, few studies were directed to explore the influences caused by the visualized teaching materials onto the cognitive process. Via ERPs, this study aims at investigating gender's behaviors and cerebral cortex activation types when people engage in 2D and 3D object recognition. Research result suggested that the correct rate of 2D tasks was higher than the 3D's; also, the response time for 2D tasks was shorter. No significant differences were found respectively from both student groups' (male and female) correct rates and response time. Through brainwave analysis, we found that both groups' P300 amplitudes at parietal lobe PZ electrode reached a significant level, and females' were greater. This result revealed that the ways of mental resource allocation were different when both genders of students underwent 2D and 3D tasks; it also explained why the visualization courses from both groups were different.

Index Terms-- event-related potentials (ERPs), object recognition, two-dimensional object (2D), three-dimensional object (3D), virtual reality

I. INTRODUCTION

VIEWING from hard-wares and soft-wares, the techniques of computer simulation and virtual reality are mature and widely employed in our daily life and learning fields. Animations can breakthrough barriers of time and space and concretely show viewers unobservable nature phenomena, promoting their comprehension about certain conceptions (de Jong & Njoo, 1992). Virtual reality is a simulated three dimensional world created by computers, which provides users with simulated visual, audio, and tactile perceptions that are as real as those in the solid world. Virtual reality is a media among the cyberspace, real world, and the users themselves. When the users change some circumstances in the real world

and transmit them into the virtual world via virtual reality systems, the virtual world will interact with the users as if they were in the real world (Dickey, 2005; Hew & Brush, 2007; Hew & Cheung, 2010). In some related studies, quite many scholars regard virtual reality a tool with great potential for promoting learning (Winn & Bricken, 1992; Dickey, 2005). However, still other researches hold different viewpoints, claiming it an issue needing further discussion – if transforming a 2D and 3D virtual instruction plot into a pure 3D one can better promote learning achievements (Bouta, Retalis, & Paraskeva, 2012). Can a 3D virtual plot effectively help students gain better learning achievements? Can students' cognitive load be declined when learning in virtual reality? These questions come from our observation toward a fact that multimedia teaching materials with poor design and inappropriate combinations do not give students much help but keep them from perceiving information well.

An early study showed that virtual reality could help learners promote visual spatial ability (Ozdemir, 2009). Yet, visual spatial ability involves different sub-dimensions such as visualization, visual relations, and orientation (Dünser, Kaufmann, Steinbügl, & Glück, 2006). Up to this date, most of the researches focus more on mental rotation and less on visualization. Studies related to Cognitive Psychology indicate that visual stimulus from 2D and 3D objects are of significant differences (Liu & Liu, 2011; Liu & Liu, 2012); however, related researches from Cognitive Psychologists over 3D-image visual perception and recognition are rare (Mitsuoka et al., 2005). When 3D virtual reality are frequently used as instructional stimulus, the consequence that if learners are able to interact and learn well with/from such material is worth of further examination. Therefore, the investigation about the cerebral mechanisms of 2D and 3D object recognition in the present study may be a reference for virtual reality or information-integrated material design in the future.

A. Related researches about gender differences

Sex-based differences in performance have been reported for complex and simple cognitive tasks (Jaušovec & Jaušovec, 2009). Men typically perform better than women on a broad range of visuospatial tasks, particularly on those requiring

*Corresponding author: chiau1105@gmail.com

mental rotation for 3D images (Voyer, Voyer, & Bryden, 1995; Weiss et al., 2003). Some studies indicated that increasing the difficulty of the tasks results in a greater gender difference, when conventional scoring procedures are used (Prinzel & Freeman, 1995). Nevertheless, females show superiority in perceptual speed and the ability to rapidly acquire the details of a visual stimulus (Kim & Petrakis, 1998; Kimura, 1999) and generalize many types of visual stimuli. Also, in selective attention tasks, females' processing entails more attentive elaboration of information content than males (Myers-Levy & Maheswaran, 1991). Inspired by the previous related researches, researchers of this study attempted to probe the differences of performances in object-recognition tasks.

Empirical evidence favoring sex differences in physiological parameters of cortical activation, while respondents were solving more complex tasks, comes also from positron-emission tomography (PET), functional magnetic resonance imaging (fMRI). It was found that for figural tasks males show significantly stronger parietal activation, while females show significantly greater frontal activation (Weiss et al., 2003).

Since this study employed ERPs techniques to conduct cerebral activity data collection and analysis, the following related literatures concerning the cerebral activation component differences between genders during visual tasks were reviewed. Gender related differences employing the ERPs methodology were mainly investigated for the P1–N1 complex and the P300 component. Numerous studies indicate that the P1–N1 complex reflects sensory and early attention processes (Luck and Girelli, 1999). Evidences indicate that the P300 amplitude is a reflection of the degree of match between the stimulus presented and the internal representation of the stimulus relevant for the task. Still others have reported that males have larger P300 amplitudes for spatial-attention tasks (Vaquero, Cardoso, Vázquez, & Gómez, 2004).

Gender related differences in EEG activity were only observed in the amplitudes of the early evoked P300 component. Women displayed higher amplitudes than men. A second finding was that these differences were more pronounced for the visual than for the auditory stimuli. No gender related differences were observed in the ERPs latencies, as well as in the amplitudes of the P1–N1 complex, and the induced gamma response. Taken all together the results suggest that the females' visual event-categorization process is more efficient than males'. The data are discussed in the theoretical framework of the evolutionary theory of human spatial sex differences.

In analyzing different components of the ERPs in the lower (N1–P1 and P300) as well as the upper frequency bands (induced and evoked gamma response), and their relation to global stages of information processing (e.g., sensory, perception, attention, categorization) we tried to determine the neurobiological underpinnings of sex differences in cognition. It was expected that gender related differences would be observed in the obtained ERPs components as well as in the

level of brain oxygenation. Based on previous research we expected higher amplitudes in the evoked gamma response and the P300 component of the visually evoked response in females. Fewer differences were expected for the auditory stimulus.

B. The physiological mechanisms for object recognition

The visual cortex plays the key role in visual perception for primates. Almost every signal from the retina goes through this zone first; then proceeds forward to other regions in charge of particular visual processing levels (Zeki, 1993). It is confirmed that the visual recognition will be processed only when the visual information reach at the temporal-parietal association area; yet, many functions involved in the two complex nervous systems are still unclear. So far, neurology revealed two major fiber-bundle systems, which perceive visual information in occipital cortex and project it into the brain. One of the systems deals with the spatial perception "where" from visual information, and the other handles object perception "what". The "where" nervous system is called dorsal pathway, through which V1, V2, and V3 go upward to the parietal cortex area, where spatial information is processed and spatial characteristics are analyzed. The "what" nervous system names ventral pathway, through which Vi, V2, V3, and V4 go downward to temporal lobe, where object recognition is conducted and the object features are analyzed (Ungerleider, & Mishkin, 1982; Goldstein, 2007). Posner (1980) indicated that the comprehension mechanism over objects includes processes of bottom-up and top-down. Bottom-up process is mainly guided by the physical properties of objects, which is also a process of automation. Top-down process is a conscious awareness, which is controlled by the knowledge and intention from schema. The object recognition is completed only when the interaction of the bottom-up and top-down mechanism is triggered.

C. Event-Related Potentials

Electroencephalogram (EEG) refers the continuous changes of cerebral potentials recorded via the electrodes positioned on the scalp. The amplitude of human brainwaves is between 10–100 μ V. ERPs stands for the brain-activity changes activated by certain physical events or mental events during a time period. The potentials can be recorded and extracted from cerebral potential signals via filter and signal-superimpose techniques. It is a non-invasive measuring technology which has become an often-used tool in experimental science area (Eimer, 1998; Luck, 2005). Furthermore, this technology is a multidimensional measurement with micro-second resolution, which offers consecutive data. And the signals recorded can be of various types. For instance, the ERPs changes may interpret the inner changes of cognitive process and further furnish researchers with related neurobiological information.

Showed in related literatures, among electrophysiological elements, P300 is a critical indicator for visual and audio recognition, and it is closely connected with the function of

making decisions and judgments; hence, P300 can be used as a tool for measuring mental resource allocation. When experiment participants pay more attention to the task trials, greater P300 amplitude will be induced; when the participants cannot positively categorize or identify a stimulus as target or non-target in a trial with higher difficulty, the P300 amplitude will decline (Luck, 2005). Mecklinger and Pfeifer (1990) utilized simple figures as stimuli to compare the differences among working memory modes for objects and spaces. The result suggested that the average P300 amplitude in parietal electrode zone reached the highest point when object-recognition tasks were conducted; while in spatial tasks, no significant P300 differences were found in forebrain and hindbrain zone. Thus, they inferred that P300 was related to the coding operation for object recognition. From literature review we noticed that the P300 of Fz, Cz, and Pz in midline zone may be relevant with the 2D and 3D object recognition mechanism. Therefore, related peaks were picked for multiple ANOVA analysis with hopes to have a clearer picture about the 2D and 3D figure recognition mechanism of human brain.

II. MATERIALS AND METHODS

This study is a 2×2 experiment designed and practiced in accordance with dimensions (2D and 3D) and consistency (match and mismatch). The experiment material sets distributed to 2D and 3D were equal – 120 trials. The experiment process was designed according to delayed-match sample tasks, which were presented respectively one after another.

Participants

The samples included 20 right-handed volunteer high school students (10 male, 10 female, mean age 17 years old) in Kaohsiung City and Pin-tong City in Taiwan. The experiment was undertaken with the agreement from participants' parents and written consent of each object, following the recommendations of the ethics committee of the Psychological Association. All participants had no history of neurological or psychiatric illness and had normal or corrected-to-normal vision.

Experiment materials

120 2D and 120 3D figures comprising 7 equally-sized rectangles were produced respectively, 60 out of each figure group were selected as consistent trials whose onset stimuli and probe stimuli were from the same figures. The other 60 figures from each group were set as inconsistent trials whose onset stimuli and probe stimuli were from different figures. A response box with two buttons respectively numbered 1 and 4 were provided for the participants to click with. Button numbered 1 was for consistent trials; button numbered 4 was for inconsistent trials.

During the experiment, each figure was presented at the center of a dark-background screen. The hint stimulus was a 15 mm × 15 mm black square with a centered red cross. The

onset stimuli and probe stimuli were white 2D and 3D figures sized 50mm×50mm. The process for presenting each set of trial was: hint stimulus (red-cross, 200 ms duration), interval (blank screen, 180 ms duration), onset stimulus S1 (1000 ms duration), interval (blank screen, 1000 ms duration), probe stimulus S2 (1000 ms duration), interval (blank screen, 1500 ms duration). The response time allowed was 2500 ms after the onset of S2. The consistent trials and inconsistent trials were presented randomly; the total time for presenting the whole trials was 5500 ms. (see Fig. 1)

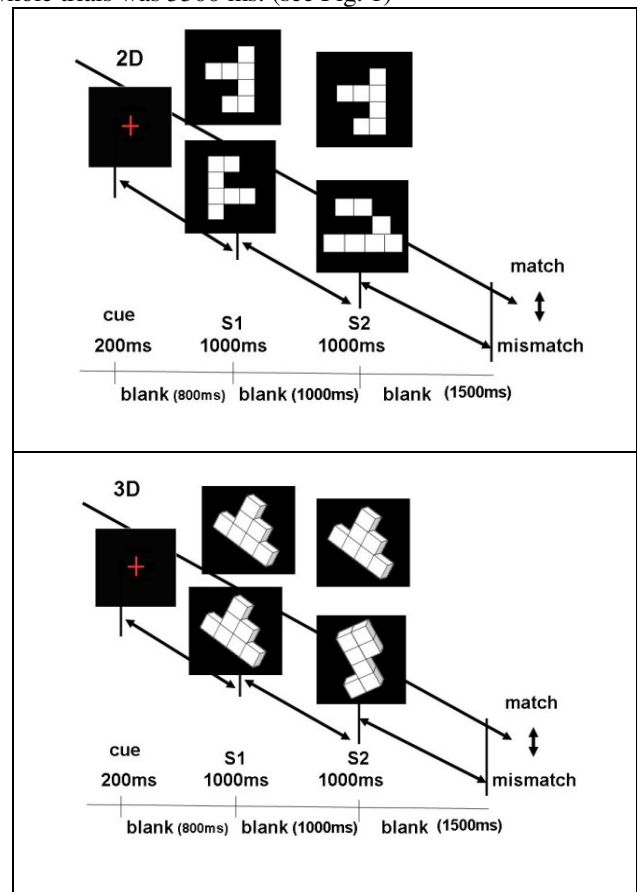


Fig. 1 2D and 3D Stimulus material design

Experiment equipment

The experiment instruments contain two parts: stimulus presentation and cerebral activity recording. Stimulus presentation was conducted by a personal computer equipped with a PentiumIII 14" LCD monitor and STIM2 software developed by NeuroSCAN Company. Two button boxes numbered 1 and 4 were connected with the computer for simultaneous response data collecting and analysis of correct rate and response time afterward. Cerebral activity recording was practiced via the instruments and devices: (a) SynAmps/SCAN4.4 amplifier to record the EEG from 32 electrodes; (b) cap with 32 electrodes arrayed according to international 10-20 system; the impedance of each electrode was under 5 k Ω ; (c) referential mastoid electrodes were placed on behind the ears; (d) the VEOG of left eye and the HEOG of both eyes were recorded through electrodes attached to both

eyes to eliminate eye-movement interferences; (e) to avoid interferences from radio-waves and noises, a copper mesh shielded soundproofing chamber with the most comfortable temperature and light was plotted for the participants.

Experiment design

The participants were seated 1.2 meter from the center of the monitor, and the visual angle was well adjusted to offer clear stimuli on the screen and to avoid vertical and horizontal eye-movement which may interfere the data collection of cerebral activities. The experiment procedure of 2D and 3D figures was conducted respectively. Each procedure lasted for about 30 minutes, and a 15 minutes' break was given between two procedures. Each participant practiced 4 trials (two matches and two mismatches) to familiarize with the task. The experiment was started with 2D trials. Before the first trial, an instruction read "Please look at the center of the screen and keep your head and body as still as possible. The red cross means the trial is to start; when the stimulus 1 and stimulus 2 are the same, please press the left button and press the right one when they are different." was shown on the screen. Participants were asked to look at each pair of 2D and 3D objects. These tasks were to identify whether the S1 and S2 were same objects (match trial) or different objects (mismatch trial) and to indicate their choice by pressing one of the buttons on a response box as quickly and accurately as possible. Aiming at the analysis toward the behavioral data of correct answers for consistent stimuli and EEG data recorded, the participants were asked to click the answer buttons with the same hand.

EEG recording and analysis

EEG was recorded from 32 Ag/AgCl scalp electrodes recording System. Using the 10-20 Electrode Placement System of the International Federation, the EEG activity was monitored over nineteen scalp locations (Fp1, Fp2, F3, F4, F7, F8, T3, T4, T5, T6, C3, C4, P3, P4, O1, O2, Fz, Cz, Pz and Oz). All leads were referenced to linked mastoids (A1 and A2), and a ground electrode was applied to the forehead. Additionally, vertical eye movements were recorded with electrodes placed above and below the left eye. Electrode impedance was maintained below 5 k Ω . The digital EEG data acquisition and analysis system (SynAmps) had a band-pass of 0.15~100.0 Hz. Prior to ERPs analysis all EEG records were low-pass filtered (30 Hz, -24 db/octave), and a correction for ocular artifacts was performed. Epochs were comprised from the -200 ms preceding and 1000 ms following the stimulus (S2) presentation. The average voltages in the 200 ms pre-stimulus period (-200 to 0 ms) served for baseline correction. The epochs were then automatically screened for artifacts. Excluded were all epochs showing amplitudes above $\pm 50 \mu\text{V}$. The ERPs averaging in unattended conditions was performed on all artifact-free epochs. In attended conditions, the averages were computed only for target stimuli. Peak-to-baseline amplitudes and latencies were determined automatically using the following time windows: P300 (280~500 ms). The electrode positions were Fz, Cz, Pz. To get a better insight into the spatial distribution of brain activity the method of low

resolution brain electromagnetic tomography (LORETA) was used (Pascual-Marqui et al. 1994). Two individually assessed time points related to the P300 were chosen for the LORETA analysis.

During the experiment, behavioral data and continuous brain-activity data were recorded simultaneously. The behavioral data comprised the onset time of each stimuli, each participant's time-spent for response, and time-spot of click. The brain-wave data were EEGs collected from 10000 sampled points per second, which showed the amplitude of each electrode and marked every trial's code and every response-click's code. Off-line analysis was conducted toward these data after the experiment was completed. The accuracy (X%) came from analytical analysis over consistent stimulus with correct answers. Response time was counted from the onset time of stimuli to the time-point of clicking the button. The response time data was the average of the consistent stimulus with correct answers; all trials with incorrect answers were excluded. The ERPs readings were analyzed by Neuroscan4.3 software, and the simultaneously recorded EEG data were analyzed off-line according to SCAN4.3 operation manual. The procedure of the analysis is listed as the following:

1. Data combination: both behavioral and EEG data were merged so that the brainwaves evoked by consistent stimulus with correct answers could be extracted (Luck, 2005).
2. Eye-movement correction: interferences caused by horizontal eye-movements and blinks were excluded by the recorded HEOG and VEOG (Luck, 2005).
3. Epoch: 200 ms prior to probe stimulus and 1000 ms for post-stimulus; the total 1200 ms was the interval between two trials.
4. Baseline correction: the baseline correction was conducted segment by segment with a 200 ms (-200 ms~0 ms) datum set before the onset of each trial.
5. Interference elimination: every brain activity of amplitude outside $-100 \mu\text{V} \sim 100 \mu\text{V}$ was eliminated.
6. Filtering: EEG data were low-pass filtered with 30 Hz/12 dB no phase shift, and 60 Hz AC interference was also eliminated.
7. Average analysis: superimposed average was practiced over all consistent probe-stimuli with correct answers. Since the correct rate was over 70%, each ERPs gained superimposed average for at least 40 times.
8. Peak extraction: the peaks of visual element P300 was extracted from 2D and 3D trials. The time windows of P300 was 280~500 ms. (Omoto, et. al., 2010; Vogel & Luck, 2000)
9. 2 \times 2 \times 3 (genders, dimensions, electrodes) 3-way ANOVA analysis was run by extracting P300 elements from FZ, CZ, and PZ electrodes in the. mid-line zone.

III.RESULT AND DISCUSSION

No significant differences were found for genders in correct rates and response time during the 2D and 3D figure recognition trials.

The quantification analysis over the average response time and accuracy were carried out by the result from consistent trials with correct answers, with which the performance discrepancy for 2D and 3D figure recognition was observed and the 2-way (genders \times dimensions) ANOVA analysis were implemented. The result is shown in Table 1.

Table 1
Summary of the t-test toward Accuracy and Response time

Variable	type	Total M (\pm SD)	Gender	M (\pm SD)
Accuracy	2D	91.59 (7.53)	Male	91.53 (5.17)
			Female	91.65 (9.65)
	3D	85.79 (11.62)	Male	84.17 (13.39)
			Female	87.40 (10.01)
Response time	2D	740.70 (188.86)	Male	745.39 (153.02)
			Female	736.00 (227.66)
	3D	789.92 (195.45)	Male	824.89 (214.53)
			Female	789.92 (195.45)

$p < .05$

The 2-way (genders \times dimensions) ANOVA analysis for the accuracy revealed that the accuracy in the interaction between gender and dimension was not significant ($F(1,18) = .76$; $p = 0.39$, $\eta^2 = 0.4$); therefore, further analysis for major-effect test was conducted, which indicated that gender diversity did not reach a significant level ($F(1,18) = 0.17$; $p = 0.69$, $\eta^2 = 0.01$). The average accuracy of the male objects in 2D trials was $M = 91.53\%$, $SD = 5.17$ and the female's was $M = 91.65\%$, $SD = 9.65$. In 3D trails, the male objects' average accuracy was $M = 84.17\%$, $SD = 13.39$ and the female's was $M = 87.40\%$, $SD = 10.01$. In contrast, the major-effect test for dimension reached a significant level ($F(1,18) = 10.60$; $p < 0.05$, $\eta^2 = 0.37$). The average accuracy from the objects in 2D trails was $M = 91.59\%$, $SD = 7.53$; in 3D trials, it was $M = 85.79\%$, $SD = 11.62$. Apparently, 2D's accuracy was superior to 3D's.

The 2-way (genders \times dimensions) ANOVA analysis for the response time suggested that the dimension in the interaction between gender and dimension was not significant ($F(1,18) = 1.87$; $p = 1.89$, $\eta^2 = 0.9$). Hence, further analysis for major-effect test was conducted and the result showed that gender difference did not reach a significant level ($F(1,18) = 0.22$; $p = 6.45$, $\eta^2 = 0.01$). The average response time of the male objects in 2D trials was $M = 745.39$, $SD = 153.02$ and the female's average accuracy was $M = 736.00$, $SD = 227.66$. In 3D trails, the male objects' average accuracy was $M = 824.89$, $SD = 214.53$ and the female's was $M = 789.92$, $SD = 195.45$. Besides, the major-effect test for dimension reached a significant level ($F(1,18) = 4.93$; $p < 0.05$, $\eta^2 = 0.22$). The average response time for 2D trials was $M = 740.70$ ms, $SD = 188.86$ and the one for 3D trials was $M = 789.92$ ms, $SD = 195.45$. Obviously, the difference of response time reached a significant level ($t(20) = -2.17$; $p < .05$). This evidenced that the average response time for 2D trials was shorter than 3D's.

Found from the analysis results of accuracy and response

time, the response time for 2D trials was shorter than 3D's. This outcome shares similarity with related mental rotation research results gained by previous researchers (Roberts & Bell, 2003; Shepard & Metzler, 1988). Shepard and Metzler (1988) regarded that the differences of dimensional stimulus lead to time differences for comparing the stimulus during figure recognition process. Besides, some research toward the complexity and integration of figures also suggested that high complexity takes longer time and vice versa (Folk & Luce, 1987; Han, Hung & Tsai, 2010; Yuille & Steiger, 1982). Thus, it can be inferred that the differences between 2D's and 3D's figure recognitions was resulted from the complexity of the figures. 2D figures were of lower complexity; the accuracy and the speed of response time of both genders did not reach a significant level. Yet, the female objects spent less response time than the male objects in 2D and 3D trials. This result seemed to echo with a previous study suggesting female superiority in perceptual speed, the ability to rapidly acquire the details of a visual stimulus (Kim & Petrakis, 1998; Kimura 1999), and generalizes many types of visual stimuli, and men subjects' typically demonstrate a distinct advantage on a broad range of visual tasks, including visual-spatial orientation.

The differences of P300 shown during the 2D and 3D figure recognition in genders

In the present study, the peak reading of P300 came from the average amplitude of electrodes Fz, Cz, and Pz in the mid-line zone. Table 2 shows the average statistical results of P300's amplitude and latency at electrode positions Fz, Cz, and Pz.

Table 2
Average amplitude (SD) and average latency (SD) at electrode Fz · Cz · Pz for genders' P300

dimension	gender	channel	Amplitude (μ V)	Latency (ms)
2D	male	Fz	5.80 (5.51)	397.70 (88.72)
		Cz	8.48 (5.62)	470.10 (85.80)
		Pz	10.89 (6.33)	491.90 (82.77)
	female	Fz	7.45 (5.11)	356.50 (33.44)
		Cz	13.14 (4.28)	416.90 (66.61)
		Pz	17.57 (3.42)	428.40 (72.99)
3D	male	Fz	2.31 (4.52)	448.70 (114.92)
		Cz	4.48 (4.01)	495.90 (116.87)
		Pz	7.31 (4.81)	488.50 (118.05)
	female	Fz	4.89 (3.56)	404.20 (114.19)
		Cz	10.34 (5.06)	466.20 (124.19)
		Pz	14.20 (3.36)	474.10 (96.66)

* $p < .05$

Three way, gender (male, female) \times dimension (2D,3D) \times channel (Fz, Cz, Pz), ANOVA analysis was conducted for P300 amplitudes from the experiment. The analytical result

suggested that the interaction among gender \times dimension \times channel appeared at P300 amplitude did not reach significant level ($F(2,36) = 0.22$; $p = 0.72$, $\eta^2 = 0.01$), neither did gender \times dimension and dimension \times channel. Only channel \times gender reached significant level ($F(2,36) = 5.99$; $p < 0.05$, $\eta^2 = 0.25$). Therefore, simple major-effect test was carried out. Analyzing P300 amplitudes from both genders at different electrode positions under 2D condition, we found that the difference between both genders at Pz electrode position was significant ($t(1,18) = -2.93$, $p < 0.05$). The P300 readings from male subjects were $M = 10.89$ and $SD = 6.33$, while the female subjects' were $M = 17.57$ and $SD = 3.42$. No significant differences were found at Fz and Cz positions. When P300 amplitudes of both genders were analyzed under 3D condition, significant difference was spied at Cz position ($t(1,18) = -2.87$, $p < 0.05$). The P300 readings of male subjects were $M = 4.48$, $SD = 4.01$, and the females' were $M = 17.57$, $SD = 3.42$. No significant difference was found at Fz position. The result of major effect test revealed significant differences, which were (a) dimension: $F(1,18) = 14.03$, $p < 0.01$, $\eta^2 = 0.44$, (b) genders: $F(1,18) = 7.82$, $p < 0.01$, $\eta^2 = 0.30$, and (c) electrode positions: $F(2,36) = 57.62$, $p < 0.01$, $\eta^2 = 0.76$.

Three way, gender (male, female) \times dimension (2D,3D) \times channel (Fz, Cz, Pz), ANOVA analysis was conducted for P300 latency from the experiment. The analytical result suggested that the interaction among gender \times dimension \times channel appeared at P300 latency did not reach significant level ($F(2,36) = 0.67$, $p = 0.52$, $\eta^2 = 0.04$), neither did gender \times dimension and dimension \times channel. Hence, further analysis toward major effect test was conducted. The result showed that the major effect test for genders did not reach a significant level ($F(1,18) = 1.69$, $p = 0.21$, $\eta^2 = 0.08$); while the major effect of electrode positions did ($F(1,18) = 15.46$, $p < 0.001$, $\eta^2 = 0.46$). A comparison over the latency of the three selected electrode positions showed that $Pz > Cz > Fz$.

From the statistical result, we found that the greatest P300 amplitude was evoked at Pz position for both genders; the difference reached a significant level, and the females' were greater than the males'. Since P300 reflects the situation of neurophysiological activation during the recognition process (Polich & Kok, 1995), it can be a tool for measuring mental resource allocation. When the stimulus categories can be ensured, the phenomena of P300 increase appears; yet, it declines when they can not (Luck, 2005). The afterward comparison revealed P300 amplitude of both genders was $Pz > Cz > Fz$, and therefore it can be inferred that both genders of students had the same mechanism for comparing and recognizing stimulus in 2D and 3D object recognition trials. However, when processing 2D and 3D objects, neural activities bear unequal mental-load, and the result of the neural activities may be an indicator for 2D and 3D object recognition for both genders of students.

P300 amplitude evoked by 2D and 3D figures also reached a significant level, and the greatest P300 amplitude showed up at Pz position; furthermore, the P300 amplitude evoked by 2D figures was greater than the one evoked by 3D's.

This consequence is the same as the research result gained by Mecklinger and Pfeifer (1996), who used simple shaped figures as stimuli to find that the greatest average amplitude would show up in parietal zone, with which they inferred P300 changes reflect the coding operation process for stimuli.

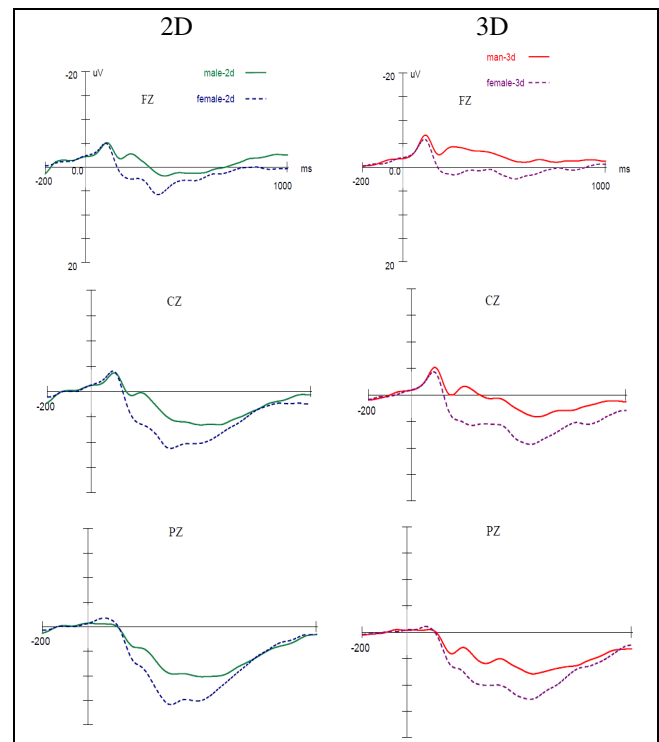


Figure 3 shows the comparison of P300 average wave forms at three electrode positions (Fz, Cz, Pz) in the brain central area during 2D and 3D figure recognition. The average P300 latency in 2D figure recognition trials was between 377 ms and 377 ms; while the one in 3D trials was between 420 ms and 481 ms. Female's average P300 amplitude was greater than male's at Fz, Cz, and Pz electrode positions.

IV. CONCLUSION

The purpose of this study was to find out the mechanisms of brainwave when human beings recognize the 2D and 3D figures under the P300. This also helped to give evidence of judging the responses of these two stimuli and the impact of gender difference. The result revealed that the ways of mental resource allocation were different when both genders of students underwent 2D and 3D tasks; it also explained why the visualization courses from both groups were different.

The results of the present study suggest that females have the better advantage of object recognition. For females, a more fully elaborated event-categorization process accompanied by a more distinct sensory input could help them to have better object recognition. However, the data in the present study have been obtained from rather simple tasks, which may put some limitations on the generalizations. Further researches employing more complex tasks in the figures as well as event related tasks will be needed to give a more exact answer to the question of whether females usually see things more carefully than men.

The results of this study provide some inspiration of virtual reality and computer simulation design. In the future, to design teaching material may need to consider the ability of the learners' spatial ability and object recognition. That is to say, the different effects of male and female students should be taken into consideration.

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BIOGRAPHIES

**Bao-Yaun Liu**

National Kaohsiung Normal University, Taiwan He received the Master Degree from Graduate Institute of Science Education in 2003. His main research interests are science education, neuropsychology, and cognition psychology. He is now an Elementary school teacher in Pingtung County, Taiwan.

**Yuan-Cheng Lin**

National University of Tainan, Taiwan He received the Master Degree from Graduate Institute of Computer Education in 2001. His main research interests are science education, neuropsychology, and cognition psychology. He is now the principal of Hu-shan Elementary school in Tainan City, Taiwan.

**Chia-Ju Liu**

She received her Doctor of Philosophy degree from the Institute of Science Education of National Taiwan Normal University in Taipei, Taiwan in August, 2000. The other qualifications she has obtained and jobs she has been practicing are listed as the following:

Professor of Graduate Institute of Science Education, National Kaohsiung Normal University. Professor of Graduate Institute of Environmental Education, National Kaohsiung Normal University. Chairperson of Graduate Institute of Science Education, National Kaohsiung Normal University. Chairperson of Graduate Institute of Environmental Education, National Kaohsiung Normal University. Director of Science Education Center. Director of Neurocognition Lab.