Research Paper

Gender Effect on Neural Correlates of Autobiographical False Memories for Brand Images

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ABSTRACT

Introduction: This study investigated the effect of autobiographical brand images on false memory formation in adults, using the category associate's procedure. The study also applied the event-related potential (ERP) approach to explore neural correlates of false memory and gender differences in false memory recall of brand images.

Methods: Eight categories of autobiographical brand images were implied in a category associates' procedure to investigate false memory recall. ERP data were obtained from 24 participants (12 females and 12 males) using a 32-channel amplifier while subjects were performing the memory task. Subsequently, gender effects on behavioral responses and neural correlates of false and true memory recalls were statistically compared using peak amplitude and latency of P300, late positive complex, and FN400 components.

Results: The results showed that left frontal areas in women were more activated in response to false memories compared to men, however, the men's brain responses were faster. In addition, the men's brain responses to false memories were widely distributed mainly over frontal, parietal, and occipital areas.

Conclusion: Males and females differently process autobiographical brand images. Nevertheless, the differential neural process may not influence their recognition rate or response time.

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Highlights

- Differential activation patterns: Exploring left frontal areas in women.
- Gender disparities in brain responses to false memories.
- Distribution of brain responses: Insights into men's neural processing.
- Unraveling the complexity of gender-specific memory encoding.
- Understanding neural mechanisms behind false memory formation.
- Impact of differential neural processing on recognition and response time.
- Implications for marketing and consumer behavior research.

Plain Language Summary

This study explores how memories of brand images can be influenced and sometimes distorted in adults. We used a technique called the category associate's procedure to examine this. Additionally, we looked at how men and women remember brand images differently, using a method called event-related potential (ERP) to observe brain activity while participants completed memory tasks. In our study, participants were shown various brand images and asked to recall them later. We recorded brain activity during this process. Our results showed that women tended to activate certain areas of their brains more when recalling false memories compared to men. However, men's brain responses were quicker, and they showed more widespread activation in different brain areas. Overall, our findings suggest that men and women process brand images differently in their brains. However, these differences might not affect how accurately they remember these images or how fast they respond. Understanding these gender-specific differences could have implications for marketing strategies and consumer behavior research in the future.

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1. Introduction

Memory and consumers' decisions

Memory plays an important role in consumers' decision-making process by determining how information about goods is perceived and recalled. Information stored in consumers' memory is consciously or unconsciously recalled when deciding to purchase a product. Therefore, understanding the nature of consumers' memory and how it contributes to purchasing will have important marketing implications (Lynch & Srull, 1982). In this regard, marketers try to create a sense of familiarity for consumers by running advertisements, which touch on consumers' autobiographical memory. Therefore, bringing back such memories makes consumers believe they know a given brand product well and have a good experience with it; therefore, they may decide to buy the product (Baumgartner et al., 1992). Specifically, a reference to memories makes consumers focus less on their logic and more on emotions triggered by those memories when deciding to buy a given product. Advertisers today are increasingly using this technique to make their products more attractive, especially to older consumers for whom the memory of good old days can reflect the continuity of vitality and youth (Braun-LaTour et al., 2004).

Influencing consumer's decision by cognitive and emotional engagement

Previous marketing research on advertisement-based memory has primarily focused on the effects of explicit memory recall (Yoo, 2007) This process involves a deliberate attempt by the consumer to recall the information of an ad by rethinking it. Findings from this line of research show that the long interval between viewing an ad and remembering it makes it difficult, if not impossible, to recover the relevant information from memory. Some other research that has focused on tacit memory (Yoo, 2007), has shown the extent to which a person's cognitive and emotional engagement with advertisement could affect cognitive processing, and influence people's decisions (O'Donnell & Brown, 2011).

Cognitive and emotional engagement by autobiographical memory recall

Considering the purchasing behavior, consumers' current decision to buy a given product is largely influenced by their past experiences with the product. The past experiences are recalled from either episodic (autobiographical) or semantic memory. The semantic form had been the primary focus of consumer research. However, the role of emotion in combination with cognitive functioning and semantic form could better provide a framework for conceptualizing consumers' decisions. So, an autobiographical form of memory can be equally influential on purchasing behavior, and would be important to consider it for a full understanding of consumers' decision-making process (McCarthy & Warrington, 2013). Autobiographical memoirs are narratives that are influenced by expectations before and after events. These narratives are also influenced by other experiences (photos, quotes from others, and even irrelevant events), our goals, and our motivations when they are recalled. Part of our autobiographical memories has been shaped by brand images. A brand can be defined as cultural symbols that are based on real or fake people, places, animals, or objects such as food products in this study. When we decide to purchase a product, brand images are also recalled. During the recall of autobiographical information, false memories may occur; and it has been shown that autobiographical brand images give a higher chance of a false memory recall (Khosrowabadi, 2020)

False autobiographical memory recall

False memory is one of the most common memory errors. Loftus argues that all memories, in essence, are false to various degrees (Loftus & Ketcham, 1996). False memories come from the same process of encrypting, reviewing, and monitoring a source (memory assignment) that creates real memories. Therefore, it is difficult to ensure the accuracy of a particular memory (Conway, 1997). Hence, some researchers have investigated the impossible memory (not occurring in reality) instead, to provide evidence for the existence of false memory. For example, Braun and his colleagues (Braun et al., 2002) were able to uncover impossible memories by manipulating a Disneyland ad. In their experiment, most of the participants remembered seeing a rabbit as a part of their experience in Disneyland. However, it could be impossible because the rabbit was a cartoon character made by Warner Bros and did not exist in Disneyland. Therefore, they indicated that the effect of an advertisement could create an experience it depending on how a person remembers (recalls) the experience (Braun et al., 2002). It is anticipated that elements or images in the advertisement influence the memory reconstruction process of the viewers, regardless of whether an event occurred or not. Therefore, ads can bring back childhood memories, and this process of imagination leads consumers to believe that the experienced events in the ads have truly occurred. Consequently, exposure to promotional images increases the likelihood of consumers mistakenly believing that they have already experienced the advertised product and results in changes in purchasing attitudes. For instance, people who read clear print ads for counterfeit products believe they have tried those products before (Scott, 1994).

Examining individual differences in memory has been a common theme for researchers, however, these studies have reported different results, with some researchers finding that women performed better in verbal memory than men in space (Calado et al., 2021; Aliyari et al., 2019).

In most studies on autobiographical memory, no significant difference was observed between the two sexes (Bauste & Ferraro, 2004), but differences were observed in the neural pathways and activated areas of the two sexes' brains. Functional magnetic imaging resonance (fMRI) studies show these differences. In the parahippocampus, the left has been for men and insula (Yu et al., 2019).

To read more (Bauste & Ferraro, 2004) in the field of false memory in general, studies do not show a difference in the behavioral scores of the two sexes (Griffin & Schnyer, 2020). In one study, by adding an emotional burden to words in the Deese-Roediger-McDermott (DRM) paradigm, the amount of false memory increased in women compared to men. No difference was found in other lists (Dewhurst et al., 2012). There are generally conflicting results in this regard. On the other hand, research shows that gender has been influential in retrieving brand names. The results of this study show that gender is related to the brand response and gender asymmetry is more prominent in product categories where masculinity-femininity is the hallmark of the product.

In another study, the authors found that while both men and women interact with brands, these relationships are more impact-based for women and more cognitive-based for men. This finding is true for respondents at younger ages. Over time, this difference between men and women narrows. At age 35, women's relationships with the brand are relatively less affected and more practical. The authors provide insights into the impact of family and peers on business relationships (Sahay et al., 2012).

Use of neuroimaging techniques to investigate the neural mechanism of false memory

In the last few decades, researchers have inclined towards using more advanced tools to study consumers' purchasing behavior and their memory formation while receiving advertisements for different brand products (Lucchiari & Pravettoni, 2012; Camarrone & Van Hulle, 2019). For instance, in the pseudo-memory research, it was shown that the prefrontal cortex and hippocampus reported in previous studies are involved in false memory formation (Schacter, 1996; Van Damme & d'Ydewalle, 2009). It has been reported that activations of some brain areas including frontal-parietal parts, left hippocampus, and bilateral middle temporal gyrus might be different for true and false memories (Dennis et al., 2008). These findings support the idea that the brain distinguishes real memories from misleading ones (Nichols et al., 2015). In terms of the memory of brand images, recent fMRI studies also showed that the frontal cortex may be very important for brand knowledge processing (Wang et al., 2012; Ma et al., 2014). Currently, many studies are examining the neural correlates of advertising and branding, seeking to deepen knowledge about consumer behavior (Perrachione & Perrachione, 2008; Aliyari et al., 2019). Nevertheless, the neural mechanism of autobiographical false memory still requires to be well understood. So, the present study aimed to investigate memory formation for the brand products, focusing on one of the biographical memory errors, namely false memory (O'Donnell & Brown, 2011). Also, efforts were made to compare the functional status of different brain areas when committing and not committing false memory errors by recording electroencephalogram (EEG) signals. Also, since a consumer's gender could influence the process of brand information (Cadavid & Beato, 2016).

To date, investigations conducted mainly using event-related potential (ERP) have been limited to false detection, the most valid parameter in distinguishing between true and false cases related to crime studies in forensic research (French, 2003). In the present study, we examined important false ERPs in a category associates procedure model. We have already identified two promising ERPs that differ between true and false recognition in category associates procedure pattern: The FN400 and a positive late component of the late positive complex (LPC) (Volz et al., 2019), and a p300 that shows the difference between the original and misleading information in the category associates procedure (Seamon et al., 2000). All three components have been confirmed in studies on the misinformation paradigm.

2. Materials and Methods

Participants and instruments

Twenty-four participants were recruited among graduate students at the Shahid Beheshti University (age: 27.16±1.7 years, 12 females and 12 males). All participants had normal or corrected-to-normal vision and were right-handed. Being between 18 and 30 years of age, and having no caffeine, alcohol, or other drug consumption within 8 hours before the experiment was considered as the inclusion criteria. Demographics of the subjects are presented in Table 1.

Table 1 shows that there is no difference between the two groups in terms of age, attention, memory, and intelligence

Stimuli and cognitive tests

A total of 160 images were selected from the data provided by Jarf Negar Cooperation. This included familiar images that had been within consumers' sight during the past five years. We did a pilot study to categorize the images and removed the most and the least familiar images and all the remaining images were normed (Shabani et al., 2022). Finally, we came up with eight categories of brand images including soft drinks, potato chips, choco-

Table 1. Demographics and cognitive scores of participants (n=12)

Characteristics / Group	Mean±SD*/(t, P)				
	Age	DASS	IQ Score	Stroop	N-back
Female	27±2.89	21.72±7.69	102.25±11.20	0.97±0.05	0.97±0.04
Male	26.08±2.02	20.56±6.38	100.58±9.68	0.96±0.07	0.98±0.06
Comparison	0.375, 0.903(0.156)	0.691, 0.402(0.288)	0.699, 0.39(0.291)	0.691, 0.40(0.288)	0.635, 0.480(0.264)

Abbreviations: SD: Standard deviation; IQ: Intelligent quotient; T: T-value of the 2-sample t-test.

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*Cohen's d.

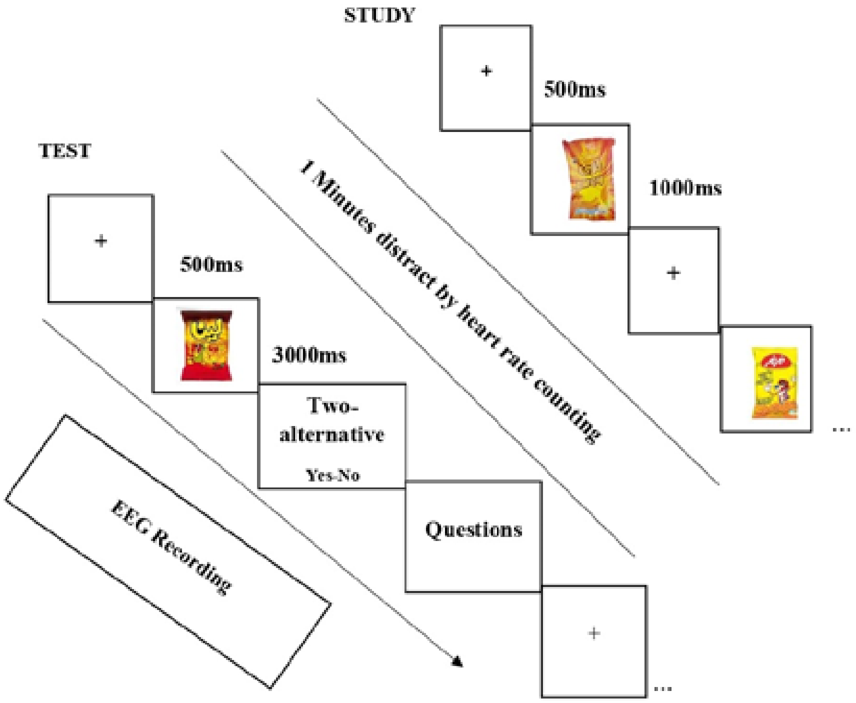

Figure 1. Category associate procedure including the study and the test/recognition phase

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late, juice, milk, snacks, cheese curls, and coca-cola. For each category, we defined a study phase during which twenty images were presented followed by a recognition memory test phase in which ten images from the study phase along with ten new images from the same category were presented. A category associates' procedure was used to develop the task.

The tasks were presented to the participants on a 32-inch screen, placed at an approximate distance of 1.4 m. Subjects' intelligence quotient (IQ) level was evaluated by the Wechsler intelligence test (Saeidi et al., 2019). The design and the implementation of the Stroop task were similar to those used by Aliyari (Aliyari et al., 2015) for measuring the attention level of the subjects at the time of the experiment. Regarding the N-back test, we followed Weng-TinlChooi & Thompson's (2012) paradigm to measure the participants' working memory scores. We also used the depression anxiety stress scale (DASS) test to assess the self-reports of individuals regarding their depression, anxiety, and tension/stress states (Jiang et al., 2020). Matlab 2014 software, was used to construct the memory computer test. This test specifies the number of false memories and true memories; besides the recognition rate, response time is also measured.

Experimental procedure

Participants were informed about the test procedure and their rights upon their arrival. They were given an informed consent for participation. None of the subjects were aware of the purpose of the experiment. However, the purpose was explained to them after the test. First, participants took the Wechsler intelligence test and the DASS test. Then the N-back and the stroop tests were administered. The cognitive tests were used to ensure the participants' normal IQ scores, memory, and mood states, and attend performances. Subsequently, a 32-channel EEG cap with 10/20 standard electrode placement was placed on the subjects' heads while they completed the cognitive tasks. After two minutes of eye close and eye open resting state, EEG data were recorded. Then, the brand images were presented to the subjects using a category associate procedure. Eight different categories of images were presented in a random order of sequence. In the study phase, the images were displayed sequentially, each lasting for a second followed by the presentation of a fixation point for 500 milliseconds. At the end of the study phase, participants were asked to count their heart rates for a minute and report the number to the examiner. This was done to create a distraction before the start of the recognition phase. In the recognition phase, 20 images were displayed one by one, with 10 images taken from the study phase and 10 new images. Upon the presentation of each image, participants had to decide whether the image was old (presented in the study phase), using a computer mouse to click either yes or no. Participants were also required to determine the level of confidence in their answers by choosing one of the three predetermined choices: Very sure, sure, and unsure. The same procedure was applied to all eight sets of images. Figure 1 presents schematics of the category associate procedure. The EEG recording was performed during both the study and test phases. The experiment was performed in a dim light, temperature-controlled, and sound-attenuated room. Participants sat on a comfortable chair and viewed the images from a distance of 1.40 m from the center of the computer screen. Graphical abstract of experimental procedure is presented in Figure 2.

In the study (encoding) phase, each trial started with a 500 ms fixation point, followed by an image (e.g. "Milk") presented on the screen for 1 second. In the test/recognition (retrieval) phase, participants were asked to make a memory judgment on each image: Whether presented in the study phase (yes/no), and answer their confidence of judgment (unsure/sure/very sure).

EEG data recording and analysis

We collected the EEG data using a 32-channel contact instruments psych lab EEG amplifier. The electrode impedances were kept below 5 KOhm. The EEG signals were recorded with a sampling frequency of 1024 Hz. The electrode placed at the right earlobe served as the reference. Moreover, the electrode on the left mastoid region was applied as the ground. Subsequently, a standard preprocessing was performed in the EEGLAB toolbox including band-pass filtering (1-40 Hz), running independent component analysis (ICA), and reducing the sampling frequency to 256 Hz to clean data from the noise and artifacts. Then, the ERPs components were extracted using the ERPLAB plugin. Using the ERPLAB, first, the behavioral data were matched with the EEG data, and segmentation was executed according to the participants' responses. Then, we created a two-variable list for the data considering markers for true and false memories. After extracting the data related to each of these two conditions, guided by previous research, we extracted the peak amplitude and latency of three ERPs components including P300, LPC, and FN400 (Volz et al., 2019). The P300 component was considered at a time range of 250-450 ms, the LPC at 450-750 ms, and the FN400 as the negative component at 250-450 ms.

Statistical data analysis

Gender differences in behavioral data

According to the participant's responses in the category associate procedure, 4 types of answers may occur. In this study, two types of stimuli were presented including repetitive and false images. Subsequently, 4 types of answers according to the yes and no answers were obtained. If the stimulus was repetitive and the person answered yes, honest (true) memory would occur; if the stimulus answered no, forgetfulness would occur. If the stimulus was false and the person answered yes, false memory would occur, and if the answer was no, correct rejection would occur. We only focused on true and false memories. After testing the normality of data distribution using the Shapiro-Wilk test, we used a paired t-test to compare recognition rates and RTs of false and true memories in male and female participants. $P<0.05$ was considered a significant level.

Gender differences in ERP components

After the extraction of ERP components (P300, LPC, and FN400) for each electrode and each subject separately, the test of normality was performed using the Shapiro-Wilk test. Then, a paired t-test was implied to compare ERP components of each channel separately in male and female participants. Subsequently, correction for multiple comparison correction was performed using the false discovery rate method (Dehghani et al., 2007)

Association between behavioral responses and ERP components

Subsequently, we calculated Pearson's correlation between significant ERP components and recognition rate and mean of response times of the subjects. To investigate the correlation between false memory and significant ERP components, we first selected those channels that were significantly different between male and female subjects for each component. Then, the correlation between ERPs and false memory rate and response times were calculated.

3. Results

Gender differences in behavioral data

First, we computed the number of truly and falsely recognized items to know whether false information was stored. As presented in Table 2 and Figure 3, the percentage of false memory recognition errors was

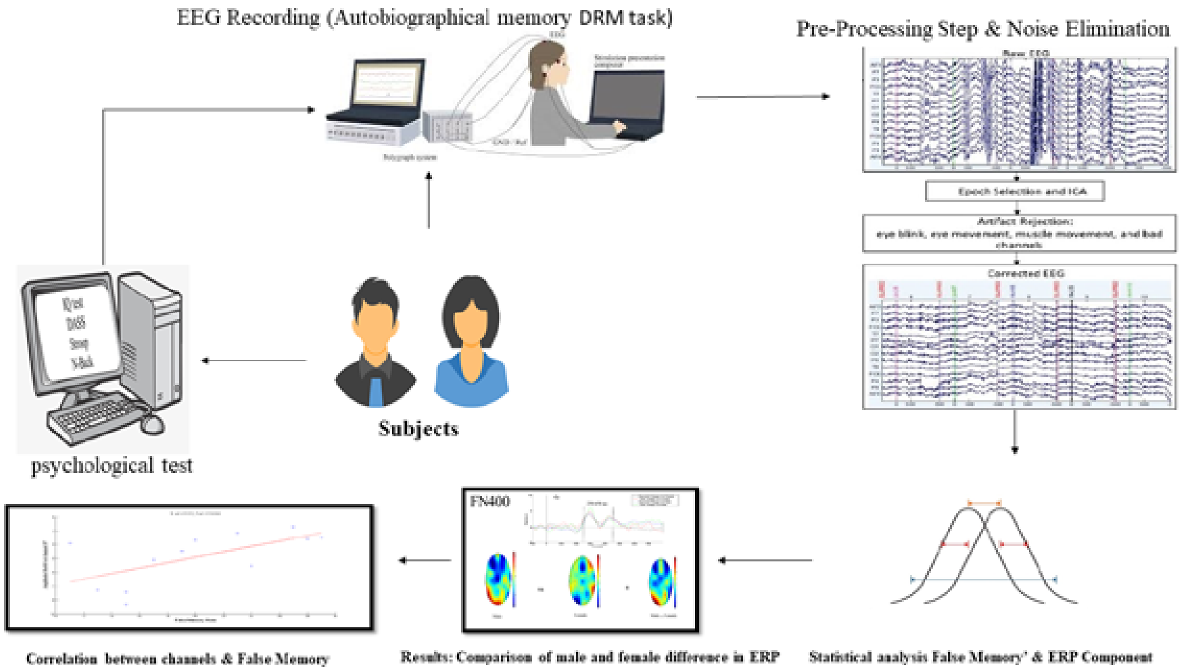

Figure 2. Illustration of experimental design and data analysis procedure NEUROSCIENCE

Note: The first male and female subjects performed behavioral tests and then performed a false memory test from which brain waves were recorded. After this step, the brain data were preprocessed and analyzed.

20.08 and 19.91 for male and female subjects, respectively. Results from the Shapiro-Wilk test (W=0.94 and SD=7.33) showed that the false memory scores had a normal distribution in both groups and true memory scores as well (W=0.9806 and SD=6.59). Meeting the normality criterion, the data were subjected to a paired t-test comparison. The result revealed no significant difference between the groups on false memory errors (t=0.4593, P=0.6505). According to the Table 2, no difference was observed between the two groups in false and true memory.

In addition, the reaction time (RT) for a false memory was the latency to report an image as old when it was not among the images presented during the study phase. Likewise, the RT for a true memory was the latency to correctly report a previously viewed image as old. In this way, we calculated mean RTs for both true and false memories and checked the normality of the data. Then, we performed a paired t-test to compare mean RTs for false/true memory in female and male participants. The results revealed a significant difference between the two groups. The results showed that the mean RT for false memory was significantly longer than for true memory (t=6.38, P=0.02 ef=2.66) in both groups. Also, the comparison of true and false memory RTs in female and male subjects showed there were no differences neither in false memory (t=2.307, P=0.941 ef=0.962) nor in true memory recalls (t=2.709, P=0.231 ef=1.129). Comparison of true and false memory reaction times in male and female groups are presented in Figure 4.

Gender differences in ERP components

We analyzed the main ERP components relevant to this research, namely P300, LPC, and FN400. The results of statistical comparisons between peak amplitude and peak latency of the ERP components in female versus male participants were as follows.

A comparison of the peak amplitude of the P300 component revealed no significant differences between the two groups of male and female participants. Nevertheless, comparison of peak latency of P300 component during the false memory, presented significant differences at C3 (t=2.3825, P=0.0266, ef=0.993), F7 (t=2.3045, P=0.0314, ef=0.961), FC3 (t=2.5245, P=0.0196, ef=1.052), T5 (t=2.2930, P=0.0318, ef=0.956), TP7 (t=2.7115, P=0.0129, ef=1.130) electrodes. Figure 5 for comparison of P300 peak latency at FC3 electrode in female versus male group.

Table 2. Group differences in rates of false and true memory recognition (n=12)

Characteristics / Group		Mean±SD		Group Comparison Female vs Male		
		Female	Male	P	t	Cohen's d
Memory	False	19.91±4.03	20.08±6.9	0.809	0.245	0.030
	True	55.33±5.49	58.66±7.61	0.239	0.518	0.501

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In addition, a comparison of peak amplitude and latency of the FN400 component, between the two groups during false memory recalls, only revealed a significant difference in peak amplitude at the T4 (t=2.3647, P=0.0281, ef=0.986) channel. Also, during true memory recalls, a significant group difference was observed in the peak latency of FN400 at the Fz channel (t=2.1471, P=0.0445, ef=0.895). Figure 6 presents comparison of FN400 peak amplitude at T4 electrode in male versus female group.

Lastly, comparing the male and female groups in the peak amplitude of the LPC component presented significant differences during false memory recalls at F3 (t=2.7746, P=0.0112, ef=1.157), P3 (t=2.4510, P=0.0261, ef=1.022), C3 (t=2.3140, P=0.0304, ef=0.965), Fp1 (t=2.2444, P=0.0372, ef=0.935), O1 (t=2.6619, P=0.0146, ef=1.110), and TP8 (t=2.1238, P=0.0452, ef=0.885) channels. In addition, comparison of peak latency of LPC between the two groups during true memory recalls revealed significant differences at C3 (t=-2.6597, P=0.0153, ef=-1.1091), F3 (t=-2.3070, P=0.0344, ef=-0.962), T5 (t=-2.660, P=0.0153, ef=-1.1092), FC3 (t=-2.1915, P=0.0393, ef=-0.9139), CP4 (t=-3.7369, P=0.0012, ef=1.558). During false memory recalls the difference in the peak latency of LPC was only observed at CP4 (t=-2.4483, P=0.0244, ef=-1.021), and T6 (t=-2.4702, P=0.0220, ef=-1.030) electrodes. Figure 7 and 8 present comparison of late positive complex peak latency at F3, and T5 electrode in males versus female group.

4. Discussion

Much research has been done, so far, on the effects of brand products on consumers. Using new research tools, studies in recent decades have tried to shed light on the neurological basis of brand products influencing consumers' purchasing behavior. In this study, we looked at the issue from a different perspective. Particularly, we studied false memory for autobiographical brand images using a category associate procedure while recording electrophysiological brain signals. Subsequently, we look at the gender effect of the formation of false memo-

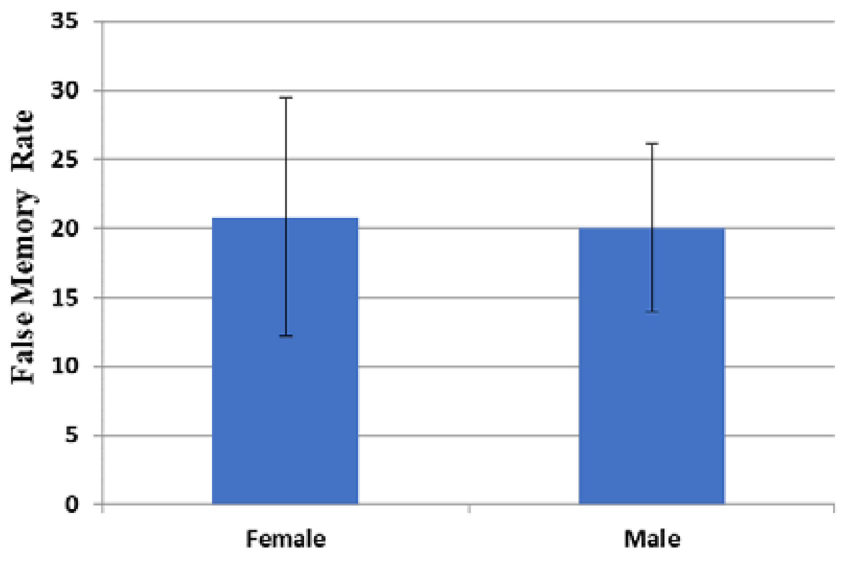

Figure 3. The mean rates of false memory recall in male and female groups

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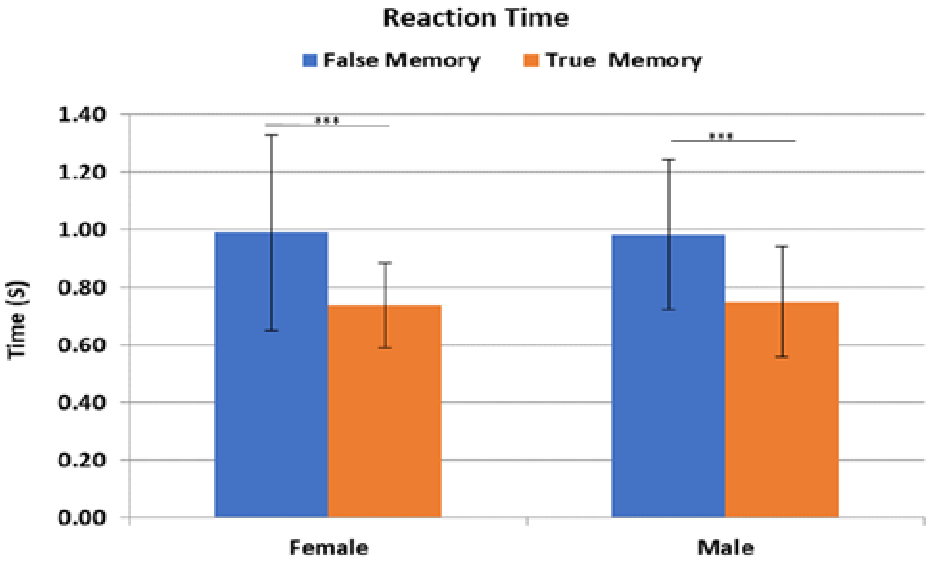

Figure 4. Comparison of true and false memory reaction times in male and female groups

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*Denotes significant group differences, P<0.05.

ries. In line with previous research, our findings suggest that gender does not affect committing false memory errors (reference), as both men and women in this study suffered from an average of 20% false memory errors However, in the analysis of neural markers, differences were observed between male and female participants in false and true memory. Moreover, participants were slower to respond to a false memory compared to a true memory. The electrophysiological analysis revealed three components related to false memory formation: P300, LPC, and FN400.

Regarding RT, participants were slower to reject a false memory item than a non-target item with a weak relevance to the lists. These results were interpreted from the perspective of activation/source monitoring theories (Aliyari et al., 2018). It seems that rejecting false memories in a category associate procedure requires a double-check against the category associate, a process that is cognitively more demanding and is reflected in participants' longer RT. The gist of all studies reviewed here is that in a false memory task, items related to the study list take a longer RT than unrelated or targeted ones. This indicates that RT can signify false memory and therefore can be used to study false memory formation.

Additionally, we examined ERP in a category associate procedure. We expected to find a false memory recognition effect in the EEG of the participants. In the ERP analysis, three interesting effects were found. First, as

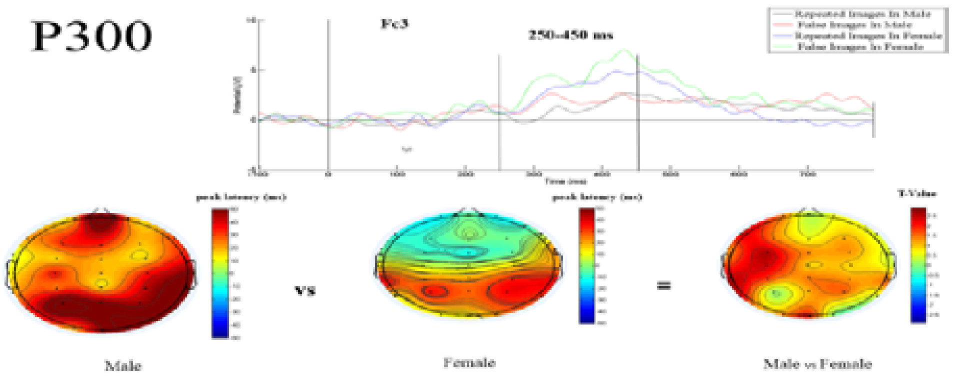

Figure 5. Comparison of P300 peak latency at FC3 electrode in female versus male group

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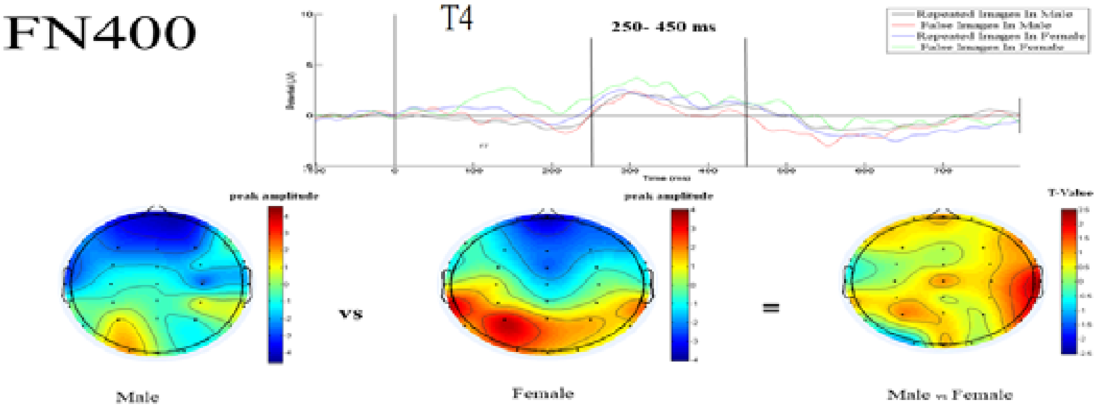

Figure 6. Comparison of FN400 peak amplitude at T4 electrode in male versus female group

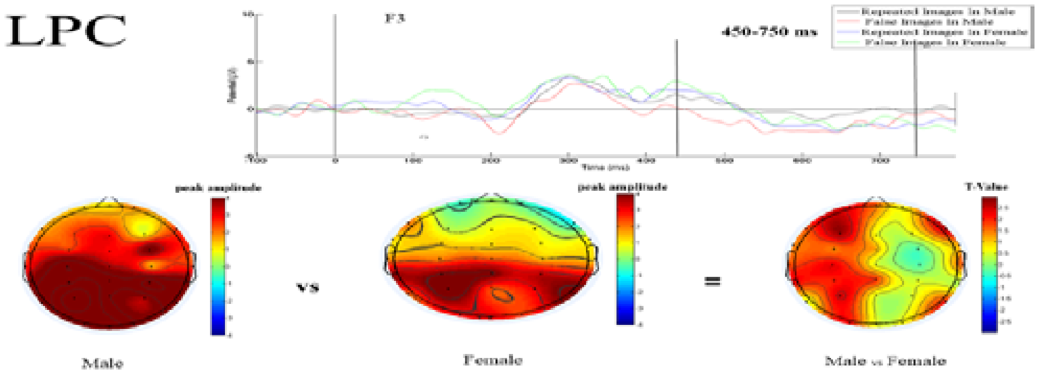

Figure 7. Comparison of late positive complex peak amplitude at F3 electrode in male versus female group

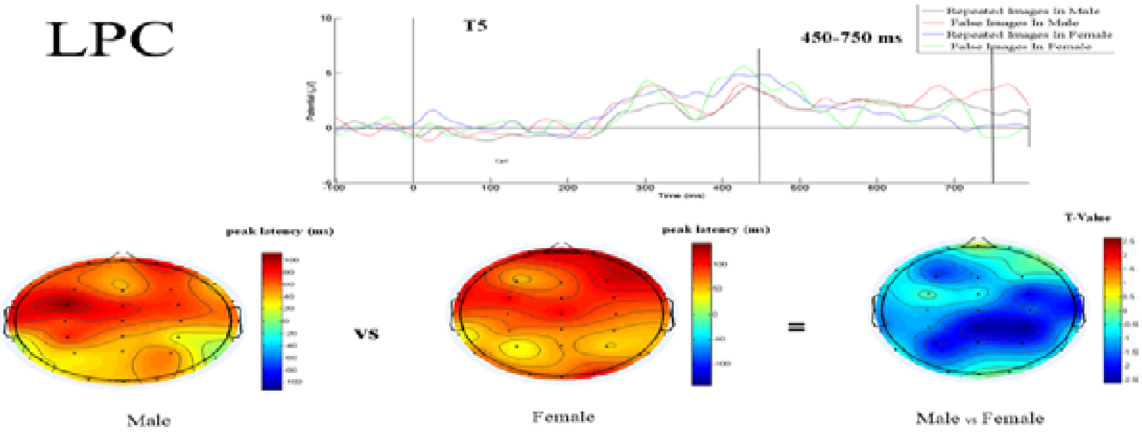

Figure 8. Comparison of late positive complex peak latency at T5 electrode in males versus female group

expected, between 300 and 400 ms after the onset of the stimuli, we found more positive amplitudes at frontal electrodes for false memories compared to true memory correctly rejected ones. This early frontal old/new effect was also found for false memories compared to those true memories. In early time windows, we found differences between true and false memories at frontal electrodes. Second, we also found an early parietal old/new effect. This was reflected in more positive amplitudes for false memories compared to true memory. We also found this effect for false memories compared to true memory. Contrary to our assumptions, we found differences between true and false memories at parietal electrode sites. Instead, we found more positive amplitudes for yes compared to no responses in parietal electrode sites. Third, later than expected, at frontal electrode sites, we found more positive slow wave potentials for false memories compared to true memories from 550 ms to 800 ms.

As expected, both false and true recognition increased the P300 amplitude beyond the recognition of comparable items. These results are similar to those of other ERP studies in which researchers did not report differences in the amplitude or topography of brain waves during true and false recognition of items in the category associate procedure. (Miller et al., 2001; Sweeney-Reed et al., 2012).

ERP features related to semantic primers and episodic retrieval provide important information about short-term false memory mechanisms. In contrast, most studies of false memory with long-term standard delays characterize ERP effects related to recovery monitoring. These findings highlight neural processing involved in memory illusions after very short delays and highlight the role of semantic processing in short-term false memory (Chen et al., 2008; Aliyari et al., 2015). Evidence for false memory processes in previous experiments with a long delay has been derived from studies of brain ERP. For example, true memory, compared to false memory, was found to induce more positive ERPs at parietal electrode sites at about 400–800 ms after stimulus onset

These parietal potentials, generally known as LPC, are related to the retrieval of episodic details of the experiment (Voss & Paller, 2007), and may indicate that details associated with study items are retrieved more than those associated with critical items. In fact, in the aforementioned studies, failure to recognize lures, compared to recognizing a new item, did not induce higher LPC amplitude, indicating that LPC does not signify false memory. In contrast, ERP components elicited with 800-ms latency have been shown to detect true memory, false memory, and true rejection of new items with the largest true memory domain and medium domain for false memory (Curran et al., 2001).

We also identified old/new positive effects of 500–700 ms, which were similar to the LPC effects identified in previous studies investigating true recognition. These effects probably reflected specific sensory details related to the study phase. False memory may also require retrieval of episodic details, but not sensory details that are available for study purposes only. LPC components are associated with the recollection of information and are elicited when details of a given event are constructed during retrieval (Tulving, 1985). Therefore, sensory details can be re-activated only during the true retrieval of information signified by LPC potentials.

The effects of the N400 are strongly correlated with semantic/conceptual processing [47], and the effects in the above-mentioned studies were similar for both true and false memory. This suggests that they reflect similar conceptual activation of both the case study and the important sediments transmitted during the study phase. These effects could be identified only in a small minority of long-term false memory experiments because the effects of N400 potentials are usually conceptually reflected in short delays (Kubota et al., 2006), and therefore, vary in terms of participation in ERP effects in long-term false memory. We, therefore, hypothesized that the effects of the N400 are particularly important for false memory in the short-term pattern (Curran et al., 2001; Camarrone & Van Hulle, 2019). In a recent experiment using fMRI to investigate false memory with the DRM paradigm, the short-term delay in the brain activity coincided with the semantic role (Bowman & Dennis, 2015). We found the FN400 negative amplitude was more associated with truly rejected items than with truly recognized items or lures labeled as old. Hence, we repeated the old/new forehead effect, which is accompanied by a sense of familiarity during recall (Curran et al., 2001).

Also, in the late windows, we found more positive slow wave amplitudes were associated with false memories, compared to true memories. This result may support the assumption that false memories in the false information paradigm are associated with a stronger sense of familiarity. However, it is inconsistent with the results of a DRM study (Nessler et al., 2001) which found the FN400 amplitude was more positive for true recognition compared to false recognition. It is also inconsistent with the findings of other false memory studies which found no differences between true and false memories in terms of the FN400 amplitude (Curran et al., 2001). These contradictory results may be due to different experimental designs. In the category associate procedure, lures that trigger false memory are new items semantically related to the items on the study list but not included in this list. In the false information paradigm, however, false memory errors are committed when there is an attribution to a wrong source (i.e. the source). Contrary to the lures in the category associate procedure, misleading information in the false information paradigm is studied and processed during the study phase and therefore may lead to a sense of familiarity during the recognition phase.

One of the limitations of this research is the small number of samples. More data can help to better understand the subject. On the other hand, network analysis can reveal neural connections between false and true memory. Based on the findings of this study, we hope that other researchers will continue this path to better understand the impact of the brand on the brain. These findings can also be used to build more effective advertising and neuromarketing studies.

This study investigated gender differences in false memory processing using ERPs. Gender differences in ERPs were evidenced over anterior locations and involved modulation of two spatially and temporally distinct components. These results are in general accordance with the view that males and females differ in the cognitive strategies they use to process information. Specifically, they could differ in their abilities to maintain information over interference and in the processing of the intrinsic contextual attributes of items, respectively, associated with the modulation of two anterior components. These interpretations support the view that processing in females entails a more detailed elaboration of informational content than in males. Processing in males is more likely driven by schemas or overall informational themes.

Based on these results, we suggest that advertisers pay attention to gender differences in terms of brain activation patterns in response to brand images while using a neuromarketing approach. We believe a correct use of false memory of brand images can be used to grow a new product faster and make an advertisement more effective.

5. Conclusion

In this study, we investigated the effect of gender on the formation of false memory and neural communication effects using EPRs. A comparison of men and women showed that there was no difference between the amount of false memory recall and response time between groups. However, false memory recall required longer than real-time memory recall in both groups. In terms of false memory neural communication, we observed significant differences between groups in peak amplitude peak and latency of ERP components in frontal and parietal electrodes. Our results showed gender-responsive activated memory networks but also provided evidence for gender-specific networks. The results showed that women's frontal brain areas activated more (e.g. right lower forehead gyrus), while men activated a distributed network including parietal and occipital areas. Given this, we assume that the positive components of ERP mainly reflect an experienced mental memory, while the negative components of the frontal areas are separately associated with true and false memories. Therefore, we think activation at the frontal areas is addictive and requires somehow enough information/activation to process it correctly. Nevertheless, since this study was the first study to explore ERP using biographical brand images in category associate procedure; further studies with a larger sample size are required to reproduce and confirm the findings.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Shahid Beheshti University (Code: IR.SBU.LCBS.97/1021). A written consent has been obtained from the participants.

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Authors' contributions

Conceptualization, study design, methodology, data collection, data analysis and writing the original draft: Mohsen Shabani; Final approval: All authors.

Conflict of interest

The authors declared no conflict of interest.

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References

Aliyari, H., Hosseinian, S. H., Menhaj, M. B., & Sahraei, H. (2019). Analysis of the effects of high-voltage transmission line on human stress and attention through Electroencephalography (EEG). *Iranian Journal of Science and Technology, Transactions of Electrical Engineering, 43*(1), 211-218. [DOI:10.1007/s40998-018-0151-8]

Aliyari, H., Hosseinian, S., Sahraei, H., & Menhaj, M. (2019). Effect of proximity to high-voltage fields: results of the neural network model and experimental model with macaques. *International Journal of Environmental Science and Technology, 16*(8), 4315-4326. [DOI:10.1007/s13762-018-1830-8]

Aliyari, H., Kazemi, M., Tekieh, E., Salehi, M., Sahraei, H., & Daliri, M. R., et al. (2015). The effects of fifa 2015 computer games on changes in cognitive, Hormonal and brain waves functions of young men volunteers. *Basic and Clinical Neuroscience, 6*(3), 193-201. [PMID]

Aliyari, H., Sahraei, H., Daliri, M. R., Minaei-Bidgoli, B., Kazemi, M., & Agaei, H., et al. (2018). The beneficial or harmful effects of computer game stress on cognitive functions of players. *Basic and Clinical Neuroscience, 9*(3), 177-186. [DOI:10.29252/nirp.bcn.9.3.177] [PMID]

Braun, K. A., Ellis, R., & Loftus, E. F. (2002). Make my memory: How advertising can change our memories of the past. *Psychology & Marketing, 19*(1), 1-23. [DOI:10.1002/mar.1000]

Braun-LaTour, K. A., LaTour, M. S., Pickrell, J. E., Loftus, E. F., & Distinguished, S. U. I. A. (2004). How and when advertising can influence memory for consumer experience. *Journal of Advertising, 33*(4), 7-25. [Link]

Baumgartner, H., Sujan, M., & Bettman, J. R. (1992). Autobiographical memories, affect, and consumer information processing. *Journal of Consumer Psychology, 1*(1), 53-82. [DOI:10.1207/s15327663jcp0101_04]

Bauste, G., & Ferraro, F. R. (2004). Gender differences in false memory production. *Current Psychology, 23*(3), 238-244. [DOI:10.1007/s12144-004-1023-0]

Bowman, C. R., & Dennis, N. A. (2015). The neural correlates of correctly rejecting lures during memory retrieval: the role of item relatedness. *Experimental Brain Research, 233*(6), 1963–1975. [DOI:10.1007/s00221-015-4268-y] [PMID]

Cadavid, S., & Beato, M. S. (2016). Memory distortion and its avoidance: An event-related potentials study on false recognition and correct rejection. *Plos One, 11*(10), e0164024. [DOI:10.1371/journal.pone.0164024] [PMID]

Calado, B., Luke, T. J., Connolly, D. A., Landström, S., & Otgaar, H. (2021). Implanting false autobiographical memories for repeated events. *Memory (Hove, England), 29*(10), 1320–1341. [DOI:10.1080/09658211.2021.1981944] [PMID]

Camarrone, F., & Van Hulle, M. M. (2019). Measuring brand association strength with EEG: A single-trial N400 ERP study. *PloS One, 14*(6), e0217125. [DOI:10.1371/journal.pone.0217125] [PMID]

Chen, J. C., Li, W., Westerberg, C. E., & Tzeng, O. J. (2008). Test-item sequence affects false memory formation: An event-related potential study. *Neuroscience Letters, 431*(1), 51-56. [DOI:10.1016/j.neulet.2007.11.020] [PMID]

Chooi, W. T., & Thompson, L. A. (2012). Working memory training does not improve intelligence in healthy young adults. *Intelligence, 40*(6), 531-542. [DOI:10.1016/j.intell.2012.07.004]

Conway, M. A. (1997). *Recovered memories and false memories.* Oxford: Oxford University Press. [DOI:10.1093/med:psych/9780198523864.001.0001]

Curran, T., Schacter, D. L., Johnson, M. K., & Spinks, R. (2001). Brain potentials reflect behavioral differences in true and false recognition. *Journal of Cognitive Neuroscience, 13*(2), 201-216. [DOI:10.1162/089892901564261] [PMID]

Dehghani, S. M., Taghavi, S. A., Eshraghian, A., Gholami, S., Imanieh, M. H., & Bordbar, M. R., et al. (2007). Hyperlipidemia in Iranian liver transplant recipients: Prevalence and risk factors. *Journal of Gastroenterology, 42*(9), 769-774. [DOI:10.1007/s00535-007-2092-2] [PMID]

Dennis, N. A., Kim, H., & Cabeza, R. (2008). Age-related differences in brain activity during true and false memory retrieval. *Journal of Cognitive Neuroscience, 20*(8), 1390–1402. [DOI:10.1162/jocn.2008.20096] [PMID]

Dewhurst, S. A., Anderson, R. J., & Knott, L. M. (2012). A gender difference in the false recall of negative words: Women DRM more than men. *Cognition & Emotion, 26*(1), 65-74. [DOI:10.1080/02699931.2011.553037] [PMID]

French, C. (2003). Fantastic memories: The relevance of research into eyewitness testimony and false memories for reports of anomalous experiences. *Journal of Consciousness Studies, 10*(6-7), 153-174. [Link]

Griffin, N. R., & Schnyer, D. M. (2020). Memory distortion for orthographically associated words in individuals with depressive symptoms. *Cognition, 203,* 104330. [DOI:10.1016/j.cognition.2020.104330] [PMID]

Jiang, L. C., Yan, Y. J., Jin, Z. S., Hu, M. L., Wang, L., & Song, Y., et al. (2020). The depression anxiety stress Scale-21 in Chinese hospital workers: Reliability, latent structure, and measurement invariance across genders. *Frontiers in Psychology, 11,* 247. [DOI:10.3389/fpsyg.2020.00741] [PMID]

Kubota, Y., Toichi, M., Shimizu, M., Mason, R. A., Findling, R. L., & Yamamoto, K., et al. (2006). Prefrontal hemodynamic activity predicts false memory--a near-infrared spectroscopy study. *Neuroimage, 31*(4), 1783-1789. [DOI:10.1016/j.neuroimage.2006.02.003] [PMID]

Loftus, E. F., & Ketcham, K. (1996). *The myth of repressed memory: False memories and allegations of sexual abuse.* New York: St. Martin's Publishing Group. [Link]

Lucchiari, C., & Pravettoni, G. (2012). The effect of brand on EEG modulation. *Swiss Journal of Psychology, 71*(4). [DOI:10.1024/1421-0185/a000088]

Lynch, J. G., & Srull, T. K. (1982). Memory and attentional factors in consumer choice: Concepts and research methods. *Journal of Consumer Research, 9*(1), 18-37. [DOI:10.1086/208893]

Ma, Q., Jin, J., & Xu, Q. (2014). The evidence of dual conflict in the evaluation of brand extension: An event-related potential study. *Journal of Management Analytics, 1*(1), 42-54. [DOI:10.1080/23270012.2014.889930]

McCarthy, R. A., & Warrington, E. K. (2013). *Cognitive neuropsychology: A clinical introduction.* Amsterdam: Elsevier Science. [Link]

Miller, A. R., Baratta, C., Wynveen, C., & Rosenfeld, J. P. (2001). P300 latency, but not amplitude or topography, distinguishes between true and false recognition. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 27*(2), 354-361. [DOI:10.1037//0278-7393.27.2.354] [PMID]

Nessler, D., Mecklinger, A., & Penney, T. B. (2001). Event related brain potentials and illusory memories: The effects of differential encoding. *Brain Research. Cognitive Brain Research, 10*(3), 283–301.[DOI:10.1016/S0926-6410(00)00049-5] [PMID]

Nichols, R., Bogart, D., & Loftus, E. (2015). False memories. *International Encyclopedia of the Social & Behavioral Sciences, 8,* 709-714. [DOI:10.1016/B978-0-08-097086-8.51034-4]

O'Donnell, E., & Brown, S. (2011). The effect of memory structure and function on consumers'perception and recall of marketing messages: A review of the memory research in marketing. *Academy of Marketing Studies Journal, 15*(1), 71-85. [Link]

Perrachione, T. K., & Perrachione, J. R. (2008). Brains and brands: Developing mutually informative research in neuroscience and marketing. *Journal of Consumer Behaviour: An International Research Review, 7*(4-5), 303-318. [DOI:10.1002/cb.253]

Sahay, A., Sharma, N., & Mehta, K. (2012). Role of affect and cognition in consumer brand relationship: Exploring gender differences. *Journal of Indian Business Research, 4*(1). [DOI:10.1108/17554191211206799]

Saeidi, M., Ostvar, S., Derakhshan, A., & Shearer, B. (2019). Psychometric properties of Multiple Intelligence Developmental Assessment Scales (MIDAS) for Adults in the Iranian Context. *Issues in Language Teaching, 8*(1), 165-194. [Link]

Seamon, J. G., Luo, C. R., Schlegel, S. E., Greene, S. E., & Goldenberg, A. B. (2000). False memory for categorized pictures and words: The category associates procedure for studying memory errors in children and adults. *Journal of Memory and Language, 42*(1), 120-146. [DOI:10.1006/jmla.1999.2676]

Schacter, D. L. (1996). Illusory memories: A cognitive neuroscience analysis. *Proceedings of the National Academy of Sciences of the United States of America, 93*(24), 13527–13533. [DOI:10.1073/pnas.93.24.13527] [PMID]

Scott, L. M. (1994). Images in advertising: The need for a theory of visual rhetoric. *Journal of Consumer Research, 21*(2), 252-273. [DOI:10.1086/209396]

Shabani, M., Salehi, J., & Khosrowabadi, R. (2022). Autobiographical brand images give a higher chance to false memory as compared to neutral images. *Basic & Clinical Neuroscience, 13*(4). [Link]

Sweeney-Reed, C. M., Riddell, P. M., Ellis, J. A., Freeman, J. E., & Nasuto, S. J. (2012). Neural correlates of true and false memory in mild cognitive impairment. *PloS One, 7*(10), e48357. [DOI:10.1371/journal.pone.0048357] [PMID]

Tulving, E. (1985). How many memory systems are there? *American Psychologist, 40*(4), 385–398. [DOI:10.1037//0003-066X.40.4.385]

Van Damme, I., & d'Ydewalle, G. (2009). A cognitive neuropsychological approach to false memory: Korsakoff patients and the DRM paradigm. *Netherlands Journal of Psychology, 64*(3), 96-111. [DOI:10.1007/BF03076412]

Volz, K., Stark, R., Vaitl, D., & Ambach, W. (2019). Event-related potentials differ between true and false memories in the misinformation paradigm. *International Journal of Psychophysiology, 135,* 95-105. [DOI:10.1016/j.ijpsycho.2018.12.002] [PMID]

Voss, J. L., & Paller, K. A. (2007). Neural correlates of conceptual implicit memory and their contamination of putative neural correlates of explicit memory. *Learning & Memory, 14*(4), 259–267. [DOI:10.1101/lm.529807]

Wang, X., Ma, Q., & Wang, C. (2012). N400 as an index of uncontrolled categorization processing in brand extension. *Neuroscience Letters, 525*(1), 76-81. [DOI:10.1016/j.neulet.2012.07.043] [PMID]

Yoo, C. Y. (2007). Implicit memory measures for web advertising effectiveness. *Journalism & Mass Communication Quarterly, 84*(1), 7-23. [DOI:10.1177/107769900708400102]

Yu, J., Tao, Q., Zhang, R., Chan, C. C. H., & Lee, T. M. C. (2019). Can fMRI discriminate between deception and false memory? A meta-analytic comparison between deception and false memory studies. *Neuroscience & Biobehavioral Reviews, 104,* 43-55. [DOI:10.1016/j.neubiorev.2019.06.027] [PMID]