Title: Brain mechanisms of persuasion:

How "Expert Power" modulates memory and attitudes

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Abstract

Human behavior is affected by various forms of persuasion. The general persuasive effect of high expertise of the communicator, often referred to as "expert power", is well documented. We found that a single exposure to a combination of an expert and an object leads to a long-lasting positive effect on memory for and attitude towards the object. Using functional magnetic resonance imaging (fMRI), we probed the neural processes predicting these behavioral effects. Expert context was associated with distributed left-lateralized brain activity in prefrontal and temporal cortices related to active semantic elaboration. Furthermore, experts enhanced subsequent memory effects in the medial temporal lobe (i.e. in hippocampus and parahippocampal gyrus) involved in memory formation. Experts also affected subsequent attitude effects in the caudate nucleus involved in trustful behavior, reward processing and learning. These results may suggest that the persuasive effect of experts is mediated by modulation of caudate activity resulting in a re-evaluation of the object in terms of its perceived value. Results extend our view of the functional role of the dorsal striatum in social interaction and enable us to make the first steps toward a neuroscientific model of persuasion.

Key words: persuasion, expertise, memory encoding, attitude, social influence, celebrities

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Introduction

Persuasion is a fundamental form of social influence on human decision making. G. R. Miller defined persuasive communication as any message that is intended to shape, reinforce, or change the responses of others (Miller, 1980). People are exposed to hundreds of persuasive messages per day in one form or another: From TV commercials to political statements to scientific publications. Persuasion has been a focus of extensive psychological research, but it has been nearly ignored by cognitive neuroscientists. The main purpose of this study is to explore the neuronal mechanisms underlying effective persuasion. The recently emerging field of social cognitive neuroscience has predominantly studied neural mechanisms of established attitudes: prejudice, implicit and explicit attitudes (see for reviews (Cunningham and Zelazo, 2007; Lieberman, 2007)). The current study investigates the brain mechanisms of the formation of attitudes, the primary target of persuasion. The vast diversity and popularity of advertising makes it an excellent vehicle by which persuasive communication can be studied (McClure et al., 2004). In advertising, a presenter (for example a celebrity endorsing a product or brand) is frequently used as a source of information. The experiment described in this paper simulates advertising and shows how and under which circumstances celebrities effectively persuade via the modulation of attitude-related neuronal activity.

Persuasion has been studied extensively in social psychology (O'Keefe, 2002; Petty and Wegener, 1998). Much research has focused on the persuasive impact of so-called source variables, which refers to aspects of the person presenting the persuasive appeal. One powerful source variable is high expertise (Cialdini and Goldstein, 2004; Eagly and Chaiken, 1993; Rhine and Severance, 1970): persuasiveness generally increases with communicator expertise. The persuasive effect of experts is based on the idea that people will believe the opinions of someone who is assumed to have a lot of relevant knowledge (French and Raven, 1960). Expertise is a major component of a persuader’s credibility (Priester and Petty, 2003), next to trustworthiness (the source's reputation to tell the truth and be honest). High credibility sources have typically been found to be more persuasive than low credibility sources (Petty and Wegener, 1998) although in certain circumstances high credibility can backfire (Tormala et al., 2006). Modern psychological models of persuasion have discovered different mechanisms explaining the persuasive power of high credibility sources. Consistent with predictions of the elaboration likelihood (Petty and Cacioppo, 1986) and heuristic-systematic (Chaiken et al., 1989) models of persuasion, and depending on the level of elaboration, source credibility has been found to operate as peripheral cue or an heuristic (as in 'experts are usually correct', (Petty et al., 1981)), to bias thoughts (Chaiken and Maheswaran, 1994), to act as a relevant piece of information for an issue (Kruglanski and Thompson, 1999), or affecting the amount of processing that occurs (Heesacker et al., 1983).

Here we focus on the expertise dimension of source credibility, and we take celebrities to effectively manipulate the level of expertise for a particular product. In advertising, immediately perceived expertise for the type of product the celebrity is hired to endorse, appears to be an important condition for increasing sales of a product. If the celebrity has no apparent expertise, the endorsement is likely to have no effect (see for details: (Rossiter and Bellman, 2005), page 177). For example, Bill Cosby played in a sitcom Dr. Huxtable, a father caring perfectly for his children. This popular role earned him the nickname "America's Dad". Thus, he was regarded as an expert for children oriented food and was very successful for endorsing a brand of gelatin deserts; at the same time, he was unsuccessful for a brokerage firm because of apparent lack of perceived expertise. Although much behavioral research has shown that our attitudes and decisions are successfully modulated by experts' opinions, the neural underpinnings of this fundamental social phenomenon are hardly studied.

Furthermore, the current study aims to disentangle brain mechanisms of persuasive expertise effects on attitudes and memory. It has been suggested that to have a lasting persuasive effect, attitude change has to be accompanied by successful memory formation (Bless et al., 2001; Sawyer, 1981). The relationship of attitudes and declarative memory has been the subject of intense research (see a review in (Eagly et al., 2001)) and recent studies suggest that memory is relatively independent of attitudes.(Cacioppo and Petty, 1989; Eagly et al., 2001). Furthermore, amnesic patients show intact attitude change but impaired declarative memory (Lieberman et al., 2001). Hence, different neurophysiological mechanisms appear to support declarative memory and attitudes. Therefore, we investigated the persuasive effects of perceived expertise both on memory and attitudes.

We hypothesized that effects of expertise can be modeled as a contextual modulation of memory- and attitude-related brain activity. We know that objects in our environment tend to appear in typical contexts. These highly predictable properties of our environment explain why the recognition of an object appearing in a typical context is facilitated (see for a review (Bar, 2004)). Similarly, we propose that a persuasive communicator creates a context for the information effectively modulating attitudes and memory. We hypothesized that the presentation of a photo of an expert celebrity before an object should alter memory- and attitude-related brain activity evoked by the object. Thus, we combined event-related functional magnetic resonance imaging (fMRI) with memory and attitude evaluation to probe neural responses to pictures of everyday objects that are modulated by perceived expertise of celebrities.

In short, while scanning, we presented young female subjects interested in celebrities and in shopping with photographs of famous persons followed by photos of everyday objects (Figure 1). Therefore, in the current design the face of the celebrity communicates the context for the object and triggers the retrieval of information linking the object to the celebrity. Overall this design imitates commercials where celebrities present (communicate) certain products or information. The expert-association between celebrities and objects was counterbalanced across subjects, so that each celebrity served equally often as an expert and a non-expert. Attitude and memory for the objects were tested one day later. In that test, photos of objects were presented alone with no celebrity context. Finally, at the end of the behavioral session, celebrities' familiarity, physical attractiveness and expertise were evaluated. This design allowed us to study whether memory and attitude-related brain activity was different for objects following experts as compared to those following non-experts.

We used the "subsequent memory effect" (*SME*) to study the neural correlates of memory formation for 'advertised' objects. The SME consistently demonstrates (Paller and Wagner, 2002) that during memory encoding, activity in the medial temporal lobe (MTL) and diverse prefrontal cortical areas is greater in response to later successfully remembered items (hits) as compared to forgotten items (misses: old items misclassified as new). Previous fMRI studies demonstrated that the context of stimulus encoding modulates SME effects in the MTL (Erk et al., 2003; Maratos et al., 2001; Smith et al., 2004). We hypothesized that brain activity in the MTL (i.e., in the hippocampus or the parahippocampal gyrus) shows an interaction between the SME for the object and the expertise of the celebrity (*celebrity expertise*: high vs. low) presenting the object. Such interaction would indicate the mechanism of memory modulation by expert power that is similar to previously reported effects of context on memory encoding (Erk et al., 2003; Erk et al., 2005; Maratos et al., 2001).

To study attitude formation evoked by experts, we introduced a "subsequent attitude effect" (SAE): we compared brain responses to later favored objects (high purchase intention) with responses to later not favored objects (low purchase intention). Thus, an interaction of the SAE with celebrity expertise should reveal the neural correlates of persuasion or attitude modulation by the perceived expertise of celebrities, i.e., by "expert power". We hypothesized that a neuronal mechanism of such attitude formation could be a modulation of caudate nuclei activity by experts. This region has been previously associated not only with learning (Cromwell and

Schultz, 2003; Delgado et al., 2003; Elliott et al., 1998; Poldrack et al., 2001; Shohamy et al., 2004; Zink et al., 2004), but also with social cooperation (Rilling et al., 2002) and trust to social partners (Delgado et al., 2003; King-Casas et al., 2005). Thus, caudate nuclei activity showing the interaction of the SAE with celebrity expertise would indicate a possible mechanism of effective persuasion based on trust and a re-evaluation of the object in terms of its perceived value.

Methods

Participants. Twenty-four healthy young right-handed females (students, mean age 21.8 years) participated in two experimental sessions: an fMRI session and a behavioral session separated by 24-30 hours. None of the subjects reported a history of drug abuse, head trauma, or neurological or psychiatric illness. Written informed consent was obtained according to the local medical ethics committee. Subjects' familiarity with celebrities was a critical pre-requirement for the study; subjects were therefore selected using a specially designed questionnaire screening their interests and shopping behavior (for additional information see Supplementary materials: Experimental Procedures).

Stimuli. 180 digital photos of celebrities (music-, TV-, sport- and movie stars) were collected. Color portraits of most familiar celebrities (e.g. Julia Roberts, Brad Pitt, Andre Agassi) with gaze contact and moderate smile were selected from a larger set of stimuli based on familiarity ratings of fourteen young females not used as subjects in the further study. The photos were projected onto a screen with a visual angle of 12.6 degrees vertically and 8.1 degrees horizontally. In addition, 360 digital color photos of both hedonic and functional everyday products (objects on white background: clothes, cosmetics, packaged food, etcetera) were obtained from publicly available internet resources. Objects with no brand labels or logos were used in order to avoid a subjective bias toward preferred brands. The size of objects was approximately 8.0°× 3.0°. Photographs were similar in terms of overall visual complexity and brightness. Pictures were used to create two sets of pairs counterbalanced across subjects (Figure 1): a) celebrities followed by a congruent object (a product that is relevant to the celebrity expertise, e.g. photo of Andre Agassi followed by a photo of a sports shoe) - *high expertise condition*, b) celebrities followed by an incongruent object (a product with no obvious link to the celebrity expertise, e.g. Andre Agassi followed by an alcohol drink) - *low expertise condition*. The expert-association between celebrities and objects was counterbalanced across subjects, so that each celebrity served equally often as an expert and a non-expert. Only gender-relevant pairs were presented (i.e., female products or unisex products since all subjects were female) to avoid a semantic conflict. Well known celebrities were used to make the level of expertise more evident and vivid. This set-up also fits the current trend in advertising, where many advertisements these days are created with little or no explicit message (examples are Nicole Kidman's print and billboard ads for perfume and Brad Pitt's for watches, both of which simply show the star and the product). This type of print ad is usually looked at for about 1.3 seconds in naturalistic exposure conditions (Kroeber-Riel and Esch, 2004) and so if the ad is going to be effective, consumers have to bring to mind the relevant expertise very quickly. In the current study celebrities and objects were presented sequentially. The celebrity first, product second sequence is in fact the usual one in broadcast ads (TV and radio) where the product or brand is presented often alone at the end of the clip to focus consumers' attention. Even in print ads, where celebrity and products are presented simultaneously, sequential separation is the intended one because these ads are usually designed such to draw attention first to the celebrity by showing the celebrity at the top and the product lower down or at the bottom. Furthermore, for print ads, analysis of eye movement data has shown that subjects will first focus on the face and eyes of the person in the ad and subsequently on the brand name or product (Pieters and Wedel, 2004).

Procedure. While being scanned, subjects attended to sequentially presented face-object pairs and indicated by appropriate button press whether or not they perceived a link between each given celebrity and the object presented thereafter. This orienting task aimed to focus subjects' attention and to link pairs of stimuli (a celebrity with an object) in a stream of rapidly presented 360 pictures that would be virtually impossible to achieve in a passive paradigm. The task was similar in all experimental conditions and imitated the typical advertising strategy: focusing consumers on celebrities who use certain products. In our study, pictures of celebrities and objects were presented separately in time to isolate the brain activity related to objects. Mean inter-stimulus interval (ISI) was 7.5 s (range: 4.5–9.5 s) and stimuli duration was 1 s. Prior to scanning, subjects practiced the task with stimuli not used in the actual experiment.

Behavioral Measures. One day later during the behavioral session, subjects' attitudes and memory were evaluated (subjects were not informed about the purpose of the second session, therefore memory and attitude tests were unexpected by participants). Recognition memory and attitude towards the objects were measured (objects were presented now without the associated celebrity). During the recognition memory test, subjects were exposed to a sequence of pictures containing a random mixture of all objects processed the day before inside the scanner and 180 new previously unseen objects (stimuli duration was 1 s). Subjects were offered three response options: (i) picture seen before with high confidence, (ii) picture not certain to be seen before, and (iii) picture not seen before with high confidence.

The subject's attitude towards the object was measured by asking participants to make an estimate of purchase incidence and indicate it on a percentage answer scale marked at intervals of 10 percentage points, that is, "0, 10, 20, …, 80, 90, 100%" (Aaker et al., 2005). Behavioral intention towards the attitude object refers to the conative component in the tripartite theory of attitude and this response may serve as an indicator of attitude (Eagly and Chaiken, 1993;

Fishbein and Ajzen, 1975). Therefore, we assume that during the fMRI session celebrities modulated the attitude towards the object that was measured using the purchase incidence scale. At the end of the behavioral session, familiarity and physical attractiveness of celebrities (presented alone) were evaluated. Finally, the level of celebrities' expertise (i.e., how knowledgeable the celebrity is about the product) for each given type of object (product) was measured. All trials were presented in a self-paced manner. We included a measure of physical attractiveness because it is a source variable that can be of influence in persuasion (McGuire, 1969) and might also vary for the selected celebrities. Therefore, we controlled the interaction of attitudes and memory with both perceived expertise and attractiveness of celebrities. The celebrity characteristics ratings were made on 11-point unipolar scales; a rating of 0 was anchored by the description "not at all…" and 10 as "very" anchored the positive description at the end of the answer scale. In the analysis of the brain data, all behavioral ratings were grouped for further ANOVA analysis in two sub-levels of studied factors: low (below the midpoint of the 11-point scale) and high levels (above the midpoint of the 11-point scale). We excluded all midpoint responses from the data processing. Behavioral results were analyzed using two-tailed paired T-tests.

Expert classification. It is important to note that in analyzing the brain data, the classification of the celebrities as experts or non-experts (and also attractive or non-attractive) was based on the subject's own responses in the post-scanning behavioral session and not on the pre-classification of stimuli. The celebrity-object expertise association was assessed by an independent group of age-matched female students (n=14) prior to the actual study while developing the stimulus set. As expected, the ratings of (post-scan) perceived expertise significantly correlated with pre-selected expertise conditions (mean r=0.64, SD =0.13). However, since perceived expertise is based on the unique, individual knowledge of celebrities' characteristics it varies across individuals, especially if one considers the large number of celebrity-object pairings (n=180). On average 22% of celebrity-object associations received a different classification (expert vs. non-expert) in the post-scan assessment as compared to the pre-scan assessment obtained in an independent sample of subjects. Thus, a classification of trials that would have been based on the pre-experimentally defined categories would contain a substantial number of false associations and thus noise. Furthermore, we conducted a statistical analysis to test the persuasive behavioral effects for pre-experimentally defined expertise. As expected, we found that the behavioral effects were strongly attenuated when the pre-experimental categorization was used as input for analysis (see Supplementary Table S3). This pattern of results clearly shows that perceived (not predefined) expertise is driving the persuasive behavioral effects. We therefore based the classification of the celebrities as experts and non-experts on individual ratings obtained in the behavioral session after scanning. We consider the use of individual ratings vital for the correct manipulation of perceived expertise, because it mimics the subjective nature of this effect. We also conducted additional analyses to test whether the conditions based on post-scanning categorization still counterbalanced each other in our study. The perfect counterbalancing of celebrity-object pairs would be indicated by the probability of 0.5 of categorization of a celebrity as an expert. In fact the average probability was 0.47 (SD=0.11) based on the post-scan assessments and did not differ significantly from the expected probability of 0.5 (one sample t-test, $p<0.3$). Thus, celebrity-object pairings were correctly counterbalanced across subjects.

fMRI Data Acquisition. fMRI was performed with ascending slice acquisition a T2*-weighted echo-planar imaging sequence (Sonata 1.5 T, Siemens, Munich; 33 axial slices; volume repetition time (TR), 2.29 s; echo time (TE), 30 ms; 90° flip angle; slice matrix, 64 x 64; slice thickness, 3.0 mm; slice gap, 0.5 mm; field of view, 224 mm). For structural MRI, we acquired a T1- weighted MP-RAGE sequence (176 sagittal slices; volume TR, 2.25 s; TE, 3.93 ms; 15° flip angle; slice matrix, 256x256; slice thickness, 1.0 mm; no gap; field of view, 256 mm).

MRI Data Analysis. Image preprocessing and statistical analyses were performed using the Brainvoyager QX, v. 1.6 software (www.brainvoyager.com). Functional images were corrected for motion and slice scan time acquisition. Because of movement artifacts (absolute maximum 1 voxel motion), two of the 24 participants had to be excluded from data analysis. Functional data were preprocessed with linear trend removal and underwent high-pass temporal frequency filtering to remove frequencies below three cycles per run (~0.001 Hz cutoff frequency). Functional images were coregistered with the anatomical scan and transformed into Talairach coordinate space (Talairach and Tournoux, 1988) using the nine-parameter landmark Brainvoyager method. Images were spatially smoothed with a full-width at half-maximum (FWHM) Gaussian kernel of 8 mm. The fMRI data were analyzed statistically by using the general linear model. For the statistical analysis, relevant contrast parameter images were subjected to a random effects analysis. In the whole brain search, the results from the random effects analyses were initially threshold at $p < 0.001$ (uncorrected), the cluster size statistics were used subsequently as the test statistic. Only clusters significant at $p < 0.05$ (corrected for multiple comparisons using minimum cluster-size statistics) are reported. Given that the MTL and caudate nucleus are regions of interest for SME and SAE, the MTL and caudate nucleus were additionally investigated within a spherical region of interest, thresholded at $P < 0.05$ (small volume corrected, radius, 10 mm; centered at ($x/y/z$) = ±30/−15/−10 and ±14/8/14) similar to previous studies (Piekema et al., 2006; Voermans et al., 2004). All local maxima are reported as Talairach coordinates (Talairach and Tournoux, 1988).

Neuropsychological studies suggest that attitudes and declarative memory can be selectively impaired and probably are represented separately in the brain (Johnson et al., 1985; Lieberman et al., 2001), and thus we investigated separately effects of perceived celebrity expertise on attitude and memory encoding. We used the SME approach as a conventional method to delineate the neural correlates of declarative memory formation (Fernandez et al., 1999; Paller et al., 1987; Wagner et al., 1998) in which later memory performance is used to back-sort neural encoding signals into events later remembered - *hits* and those later forgotten - *misses* (mean number of hits trials per experimental condition was 55.3, mean number of misses was 27.6). To study attitude formation, we introduced the SAE comparing brain responses to later favored objects (high estimates of purchase incidence) with responses to later not favored objects (low estimates of purchase incidence) (mean number of low purchase incidence trials per experimental condition was 34.3, mean number of high purchase incidence trials was 28.7). Due to an insufficiently small number of trials (less then 16) in one of the experimental conditions, four subjects were excluded from the analysis of SME (less then 20 misses per experimental SME condition); six subjects were removed from the analysis of SAE since these subjects demonstrated a strong bias towards preferring or rejecting most of the objects (the high estimate of purchase incidence condition contained less then 20 trials). Remaining subjects showed the same behavioral effects as the entire group (two-tailed T-test, corrected for multiple comparisons): the significant effect of the *celebrity expertise* on attitude ($t(15, 1) = 2.2$, $p<0.05$), the significant effect of *celebrity attractiveness* on attitude ($t(15, 1) = 2.1$, $p<0.05$), and the better memory for objects presented by experts than by non-experts ($t(17, 1) = 2.1$, $p<0.05$).

The following 2x2 factorial designs were used for the analysis of brain activity:

- subsequent attitude effect (SAE: favored vs. not favored objects) and celebrity expertise (low vs. high);
- subsequent attitude effect (SAE: favored vs. not favored objects) and celebrity attractiveness (low vs. high);
- subsequent memory effect (SME: hits vs. misses) and celebrity expertise (low vs. high);
- subsequent memory effect (SME: hits vs. misses) and celebrity attractiveness (low vs. high);

Correlation of the recognition memory performance with the attitude towards the object was extremely weak (r = 0.053, tested across all items and subjects) which additionally ensured us that SME and SAE are of different, largely independent nature. Again, the aforementioned stimuli classification was based on subject's own responses in the post-scanning behavioral session and not on the experimenter's classification of stimuli.

Results

Behavioral results: Experts affect memory and attitude

We found strong persuasive behavioral effects of experts (Table 1). The effect of *celebrity expertise* on the attitude towards the object was significant ($t(22, 1) = 3.8$, $p = 0.001$), due to a higher purchase intention for an object that followed an expert-celebrity during encoding (44.3%, SD = 12.5) than objects that followed non-experts (39.6%, SD = 9.7). Therefore, the high level of celebrity expertise made the attitude more favorable by 4.7% (that is equivalent to 12 percents relative difference of the attitude for objects that followed experts as compared to those followed non-experts). *Celebrity attractiveness* also showed a significant effect on attitude ($t(22, 1) = 2.3$, $p = 0.03$): Subjects showed a higher preference for objects associated with physically attractive celebrities (44.0%, SD = 12.1) as compared to objects associated with less-attractive celebrities (41.7%, SD = 10.1).

Recognition memory performance remained clearly above chance level: $t(22,1) = 12.7$, $p = 0.0001$ (one sample t-test), the mean hit rate corrected by the rate of false alarms and excluding uncertainty responses was 68%. Subjects demonstrated better memory ($t(22, 1) = 2.7$, $p = 0.006$) for objects presented by experts (probability hits corrected by probability false alarm: 70.6%, SD = 17) than by non-experts (64.4%, SD = 16), whereas celebrity attractiveness showed no effect on subjects' memory. Overall, our results show that experts increased the probability of object recognition memory by 6.2% (or 10% relative improvement for high as compared to low expertise trials, see supplementary Tables S1-2 for further details).

In addition, we checked the effects of the orienting task in the scanner (the task of perceiving a link or not between the celebrity and the object: *perceived link*) on memory and attitudes. First of all, the linking task was not equal to the expertise rating obtained after scanning: only 66.6% of the perceived links where perceived as expertise links. Moreover, a two-way ANOVA with the factors *link* and *expertise* revealed a significant main effect of expertise on attitudes towards the objects (F(15,1)=12.7, p<0.005), but no effect of the factor *link* (F(15,1)=2.8, p=0.11). In addition, no interaction between the factors was found. Therefore, we can assume that the linking task had no significant effect on differences in attitudes. A two-way ANOVA with the same factors on memory performance revealed a significant interaction between both factors (F(17,1)=13.97, p=0.002). The interaction was based on a significant memory effect of expertise only in cases when subjects detected a link between celebrities and objects. However, it is not surprising that a link identified during scanning was a prerequisite for the memory effect of expertise, given that the "no link" bin contained a very low number (range: 1-11 trials) of high expertise associations. Memory was not affected by the *link* factor itself.

Taking into account a slight correlation (r=0.26, SD= 0.09) between the *link* and *expertise* factors and the small number of trials in the "no link&expert" bin, we additionally conducted one-way ANOVA analyses (with three levels: "link&expert", "link&non-expert", "no link"). We found a statistically significant main effect on attitudes ((F(15,1)=8.1, p<0.01) and memory ((F(17,1)=6.1, p<0.01). Planned comparisons revealed a more positive attitude and better memory toward objects that followed experts with perceived *link* ("link&expert") than toward objects in other bins ("link&non-expert" and "no link trials"), t(15, 1) = 4.6, p <0.001 and t(17, 1)=3.4, p <0.001, respectively. Furthermore, we found no significant difference of attitudes and memory for objects in the "link&non-expert" and the "no link" bins. Therefore, these additional analyses revealed that the persuasive effect of expertise on memory and attitudes is driven by the celebrities' expertise and not the linking task done during scanning.

In sum, the behavioral results show that exposure to 180 celebrity-objects pairs, results one day later in better memory for and a more favorable attitude towards those objects that were perceived to be presented by an expert.

fMRI results

Tables 2 to 4 list regions of activity increases associated with studied effects. Figures 2 and 3 represent selected statistical maps and time courses of averaged brain activity. It is important to note that our event-related fMRI analysis was time-locked to the onset of object presentation and thus independent of direct effects of celebrities preceding the presentation of objects by 4.5 to 9.5 seconds.

Subsequent attitude effect (SAE)

While the main effect of the factor *SAE* did not reveal any activity increase for favored objects as compared to not favored objects, activity in a distributed cortical and subcortical network was stronger for not favored objects as compared to favored ones (Table 2). Anteriorly, it comprised the superior and middle frontal gyrus, cingulate gyrus and insular cortex. In the MTL the amygdala and parahippocampal gyrus were activated (Figure 2A). Posteriorly, the set of activations included the middle occipital gyrus, lingual gyrus, the superior temporal gyrus, the cuneus and the posterior cingulate. Subcortically, the caudate nucleus and the ventral posterior medial thalamus were also activated by not favored objects. Previous studies have associated each of these areas with processing of negative, aversive information and negative attitudes (Coricelli et al., 2005; Cunningham et al., 2003; Cunningham et al., 2004a; Cunningham et al., 2004b; LeDoux, 2000; O'Doherty et al., 2003).

Subsequent memory effect (SME)

The inferior and middle frontal gyri, anterior cingulate gyrus, the caudate nucleus, the globus pallidus, the parahippocampal gyrus, the hippocampus, the fusiform gyrus, the middle temporal gyrus, and the middle occipital gyrus all yielded greater activity for subsequently remembered than forgotten objects (Table 3, Figure 2B). This activation of brain regions, known to be involved in declarative memory encoding (Brewer et al., 1998; Fernandez et al., 1999; Wagner et al., 1998), confirmed the sensitivity of the SME paradigm applied here (for additional discussion, see Supplementary materials: Subsequent memory effect (SME)).

Celebrity expertise affects processing of objects

The analysis of the main effect of the factor '*celebrity expertise'* clarified how experts modulate neuronal processing of subsequently presented objects independently of behavioral effects. We found that objects following celebrities with high expertise elicited stronger activation than objects presented by non-experts in brain regions (Figure 2C and Table 3) associated with semantic processing (left PFC, anterior cingulate, superior temporal sulcus) (Kraut et al., 2002; Leveroni et al., 2000), retrieval of episodic and autobiographical memories (Maguire, 2001; Moscovitch et al., 2005) and in mentalizing about thoughts, intentions or beliefs of others referred to in the "theory of mind" (see for recent reviews, (Gallagher and Frith, 2003; Singer, 2006). Thus, our neuroimaging results indicate that experts induced a semantic or social context for the objects, which can be used for conceptual, associative processing. Moreover, activity in the posterior superior temporal sulcus and adjacent regions was previously observed when subjects made trustworthiness judgments of faces (Winston et al., 2002). Therefore, superior temporal sulcus activity in our study could reflect active processing of celebrity's personality, desires and intentions. Overall, in our study, photos of objects following those of experts induced distributed left-lateralized brain activity indicating active semantic elaboration and theory of mind judgments.

Effects of attractiveness

We found no activations demonstrating the significant main effects of the factor '*celebrity attractiveness*'. Moreover, we did not find any interaction between the factors '*celebrity attractiveness'* and *'subsequent attitude effect' (SAE).* The behavioral effect of attractiveness in our study might be too small to be detected at the neural level. Additionally, the variability of celebrity attractiveness in the current study might have been too small to effectively manipulate the factor of attractiveness in fMRI data. Overall, subjects found the celebrities moderately attractive (mean attractiveness 4.8, SD = 2.4 using an 11-points unipolar scale of attractiveness, ranging from 0 to 10). On average, only 3 celebrities out of 180 were perceived as very attractive and only 9 as absolutely non-attractive. Such relatively small variability of attractiveness might also explain why no main effect was observed for the factor 'celebrity attractiveness'. In contrast, the factor of celebrity expertise was very successfully manipulated in our study: celebrities classified as experts had much higher perceived expertise (mean expertise = 7.7 on an 11-points unipolar scale of expertise ranging from 0 to 10, SD = 1.3) than non-experts (mean expertise = 2.2, SD = 1.4).

Persuasive expertise effects on attitude- and memory-related neural activity

Probing the interaction between the factor of '*celebrity expertise'* on the one hand and the *SAE* and *SME* factors on the other hand aims at revealing the neural underpinnings of our behavioral finding of a more favorable attitude and better memory for objects presented by experts as compared to objects presented by non-experts. We found an interaction between the factor '*celebrity expertise'* and *SAE* in a set of brain structures including the superior frontal gyrus, left and right caudate nuclei (Figure 3A and Table 4). Celebrities with high expertise evoked particularly enhanced caudate activity to objects that were later evaluated as attractive. This result suggests that modulation of caudate activity is involved in triggering the persuasive behavioral effect of experts.

In addition, we found an interaction of *celebrity expertise* and *SAE* in the dorsomedial prefrontal cortex (PFC). This brain area has been associated with subjective intensity of emotions and interaction of emotional evaluation with attention (Anders et al., 2004; Cromwell and Schultz, 2003; Dolcos et al., 2004; Elliott et al., 1998; Grimm et al., 2006; Gusnard et al., 2001; Northoff et al., 2004; Zink et al., 2004). Taking into account that both the caudate nucleus and the dorsomedial PFC are generally involved in processing emotional stimuli, monitoring of action-outcome contingency (Yin and Knowlton, 2006), we can assume that the persuasive effect of experts at the final stage is predominantly based on an emotional reaction, that modulates the subject's attitude towards any given object. Observed modulation of caudate and dorsomedial PFC activity may thus explain our behavioral results, showing the striking effect of celebrity expertise on the attitude towards objects. Observed differences of attitudes can only be explained by changes of attitudes, because our celebrity-object pairings were counterbalanced across subjects. Thus, we can assume that the only reason why attitudes for objects presented with an expert differed from attitudes for objects presented together with a non-expert is a modulation of attitudes by perceived expertise.

Effective persuasion not only affects attitudes but also memory. To reveal the neural underpinnings of this behavioral effect we analyzed the interaction between the factors '*celebrity expertise*' and *SME*. The behavioral effect was paralleled at the brain system level: we found an interaction of the perceived expertise and activity associated to successful memory encoding, first of all in the MTL and related regions (Figure 3B and Table 4): hippocampus, parahippocampal gyrus, lingual gyrus, fusiform gyrus and cingulate gyrus were activated by later successfully recognized objects presented in the context of an expert celebrity. All above-mentioned structures are known to be involved in successful declarative memory encoding (Paller and Wagner, 2002). Our finding suggests that the facial context does directly modulate (enhance) encoding activity and therefore optimizes memory formation.

Discussion

In the present study, we found that experts made the attitude toward objects more favorable by 12% and increased the probability of object recognition by 10%. In everyday life, the apparent expertise of the communicator has a striking impact on persuasion. Earlier studies (Jordan, 1993; Page et al., 1987) showed that a single expert's publication in The New York Times newspaper, or broadcasting the expert's opinion on national TV, can change public opinion on policy issues by up to four percent. Similarly, in advertising, expert celebrity-product pairings can be very successful, such as Tiger Woods for golf equipment or celebrity chef Jamie Oliver as the presenter for a U.K. food retailer, with his addition to the brand estimated to have resulted in about $400 million in incremental profit over five years (Pringle, 2004). Our behavioral results for attitude formation confirm the typical finding in the psychological literature that high expertise sources are generally more persuasive (O'Keefe, 2002; Petty and Wegener, 1998; Rossiter and Bellman, 2005), whereas the neuroimaging results revealed the neural underpinnings of such persuasive behavioral effects.

As we expected, the interaction of celebrities' expertise and attitudes toward objects was found in a set of brain structures including the left and right caudate nuclei. Feedback processing and learning have been previously associated with neuronal activity in the caudate nucleus (Cromwell and Schultz, 2003; Delgado et al., 2003; Elliott et al., 1998; Poldrack et al., 2001; Shohamy et al., 2004; Zink et al., 2004). Substantial evidence implicates the caudate in reward-related tasks, including responses linked to positive affect, expectations or receipt of reward (Apicella et al., 1991; Kawagoe et al., 1998; Lauwereyns et al., 2002). Activity of the caudate was also connected to social cooperation (Rilling et al., 2002) and social conflict (Berns et al., 2005). Recently, the role of the caudate in processing such social information as perceived fairness of social partners, was demonstrated (Delgado et al., 2003; King-Casas et al., 2005). It has been shown that caudate activity correlates with the "intention to trust" on the next play of a trust game and with player reputation development (King-Casas et al., 2005). Moreover, the perceived trustworthiness of the playing partner modulated caudate activity to the outcome (feedback) of the game (Delgado et al., 2005). The trustworthy partner reduced the difference of responses to positive and negative outcomes. Even punishment or violation of trust increased caudate activity (de Quervain et al., 2004). Consequently, in the current study, we propose to interpret the persuasive effect of a celebrity with high expertise for the object, in terms of inducing "trust" to the object (inducing trust to the product's quality) and in such a way modulating the attitude towards the object. It is important to stress here that high expertise induces trust to the object (product), as in everyday life where we state that 'we trust the opinion of the expert for this product or topic'. This effect should be clearly distinguished from trust in the person as a general characteristic (i.e., celebrity trustworthiness: having a reputation to be honest). Whereas expertise can only be established in connection to an object or message (i.e., an expert source possesses the requisite knowledge for this object), trustworthiness exists independent of an object or message. Since we counterbalanced celebrities in our study and presented the same celebrity both in the role of expert and non-expert, celebrity trustworthiness cannot explain the current results. Alternatively, the level of ambiguity in choices has been shown to be negatively correlated with activity in the caudate nucleus (Hsu et al., 2005). Therefore, persuasive information can also compensate a shortage of relevant information about new objects and modulate the degree of uncertainty. Overall, an expert might decrease the perceived risk of purchasing an unknown object. Thus, our results demonstrate that experts effectively modulate activity in neural structures (i.e., caudate nucleus) involved in trustful behavior and risk evaluation. We suggest that the persuasive effect of experts is mediated by the modulation of caudate activity resulting in a re-evaluation of the object in terms of its perceived value, related attitudes or risk-reward tradeoffs.

A large body of literature shows that recent exposure to a target makes the target more readily accessible in memory; as a result, this increased accessibility enhances the fluency of target recognition, which is referred to as "processing fluency" (Jacoby and Dallas, 1981). Similarly, "conceptual fluency" reflects the ease with which the target comes to mind and activates meanings (Hamann, 1990). There is a considerable evidence that processing and conceptual fluency are affectively positive (Lee and Labroo, 2004; Reber et al., 1998). Thus, in the current study celebrities could prime the congruent objects and facilitate processing and conceptual fluency resulting in positive attitudes. On the other hand, our behavioral results showed that the perceived link between celebrities and objects, indicating the strength of a general conceptual association within celebrity-object pairs, did not affect attitudes. Therefore, our results suggest that fluency per se does not explain the entire behavioral effect of expertise that is probably based on an emotional re-evaluation of objects.

Importantly, the fMRI method is correlational in nature, which creates a causal ambiguity (Cacioppo, Berntson et al. 2003). The alternative account predicts a random classification of celebrities as experts or non experts due to neural "noise". On the contrary, the expertise ratings significantly correlated with pre-selected *high expertise condition* (on average r=0.64, SD =1.3). It means that classification was not random which makes the alternative interpretation of the results implausible. In the future, it would be important to study other aspects of expertise, e.g. professional expertise (such as a doctor in a white coat endorsing a medication) that allows unambiguous pre-experimental manipulation of expertise and resolves causal ambiguity.

In accordance with our hypothesis, persuasive effects on memory could be explained in the framework of contextual memory studies. Previous fMRI studies reliably demonstrated that emotional context of stimulus encoding modulates SME effects in the MTL, fusiform and lingual gyri (Erk et al., 2003; Maratos et al., 2001; Smith et al., 2004). Context was often manipulated by overlaying emotionally neutral stimuli on various emotional stimuli:

emotionally neutral words overlaid on emotionally positive, negative or neutral pictures (Erk et al., 2003); neutral words included in affective sentences (Maratos et al., 2001); emotionally neutral objects superimposed on negative, positive or neutral backgrounds (Smith et al., 2004). One recent study (Adcock et al., 2006) showed that MTL activity preceding the stimulus to be memorized is modulated by the emotional context (high or low level of motivation) and reliably predicts memory encoding. Previously mentioned paradigms are quite similar to the presentation of products in advertising where neutral objects often overlay on or follow the emotional context. Therefore, the modulation of MTL activity can be an important target of effective persuasion. Enhanced MTL activity strengthens the memory of an object (i.e. the increase of “brand awareness”), which is an important marketing objective aiming to narrow the consumer’s selection of a product to a list of familiar and well-known brands (these familiar brands comprise the so-called awareness set). Consumers more probably consider and choose a product from the awareness set (Peter and Olsen, 2005). Alternatively, observed persuasive memory effects could be based on semantic priming mechanisms: the facilitated processing of an object following prior experience with a semantically related stimulus (a celebrity) (Meyer and Schvaneveldt, 1971). However, our results contradict with the repetition suppression usually observed in semantic priming experiments – repeated stimuli (similar or semantically related) are typically associated with decreased brain responses (Henson, 2003). Another alternative explanation for the persuasive effect could be that an expert, e.g. a tennis player, activates a schema of tennis, facilitating thereby schema-driven processing of semantically related objects. In fact, such schema-driven processing could be an intrinsic part of the persuasive effect of expertise. Additional studies are needed to further explore the relationship between these processes (Lieberman et al., 2004; Tse et al., 2007).

The main effect of attitude (*SAE)* revealed activity in a distributed cortical and subcortical network that was stronger for unfavorable as compared to favorable attitudes: prefrontal, cingular, occipital and insular cortices, amygdala and parahippocampal gyrus. Previous studies have associated each of these areas with processing of negative, aversive information and negative attitudes (Coricelli et al., 2005; Cunningham et al., 2003; Cunningham et al., 2004a; Cunningham et al., 2004b; LeDoux, 2000; O'Doherty et al., 2003). Our results support the recent hypothesis that the amygdala and bilateral parahippocampal regions are implicated in the emotional evaluation of attitude (Wood et al., 2005). A recent study (Knutson et al., 2007) demonstrated that product preference and subsequent purchasing was correlated with deactivation of the insula. We found brain activity related to negative attitudes and no activity related to positive attitudes (see for similar results (Cunningham et al., 2003)). A lack of positive effects could be related to the selection of objects in our study because we did not pre-select objects with above average attractiveness as in the study that additionally reported some positive effects (Knutson et al., 2007). Thus, our findings seem in line with the behavioral evidence that in economic decisions, people are more concerned with avoiding losses than acquiring gains (Kahneman and Tversky, 1979). Also, from a decision making perspective, it is critical for survival of an organism to be able to decline quickly the many irrelevant choice options and to consider the small list of positive alternatives. From these results we conclude that the distributed set of brain regions that includes a number of limbic structures is selectively activated by negative attitudes that are very instrumental for buying decisions.

Finally, one may ask what we have learned about persuasion from using neuroscience that we did not know from existing behavioural research already? Firstly, the current study brings a neurobiological account to the research of persuasion, i.e. our study more precisely specifies which processes are underlying the well-known persuasive effect of expertise. Whereas under low elaboration expertise is generally considered to work as a peripheral cue, on the neural level expertise appears to activate a combination of three processes: more semantic processing and elaboration on the celebrity-object combination, (leading to) a deeper encoding of the object, and an emotional induction of trust to the object. Furthermore, our study hopes to bridge fields of neuroscience and psychology, and contribute to an evolving interdisciplinary perspective on persuasion. Traditionally, behavioural persuasion research conceptualizes the persuasive impact of source variables (e.g. source expertise) as an effect of context of communication (O'Keefe, 2002). We show how neuroscientific tools developed to investigate neural contextual effects (Bar, 2004; Erk et al., 2003; Erk et al., 2005) can be applied to the study of persuasion. We have demonstrated that the expert context modulates memory formation at the level of the MTL and attitude formation at the level of the caudate nucleus. Moreover, the observed declarative memory and attitude routes of persuasion are parallel and rather independent (Lieberman et al., 2001). Finally, our findings indicate that attention modulation probably is not a major mechanism of "expert power", i.e. we did not find persuasive effects in sensory cortices. After this first step, further neuroimaging studies of persuasion probing the effects of persuasive messages, different levels of elaboration, and various attributes of communicators are needed to help to understand better the mechanisms underlying psychological theories of persuasion. The current study investigated neural mechanisms of persuasion predictive for subsequent attitudes and recognition. Thus, we studied processes of "persuasion per se" and not simply consequences of processing of objects following being persuaded. One can speculate that if objects are later encountered again, it will trigger brain processes related to more positive emotional evaluation, fluent processing and extensive associative retrieval. Thus, the processing might pave the way for more favorable attitudes (activating ventral striatum) and stronger integration into semantic schemata (PFC and MTL).

Conclusions

Our results show that a single short exposure to an expert results in long-term modulation of memory and attitude for an object following the expert shortly after. Our results indicate a combination of routes of neural processing underlying these persuasive effects of expertise. First off, a celebrity with perceived expertise induces left lateralized activity due to higher elaboration of celebrity-object pairs, i.e. the retrieval and processing of semantic (social) information related to the celebrity and the object. Secondly, objects to be avoided trigger emotional processing retrieving initial attitudes within the amygdala and insular cortex. Thirdly, experts enhance MTL activity related to successful memory formation resulting in better memory of the objects. Finally, experts modulate caudate and dorsomedial PFC activity that predicts more favorable attitudes toward the objects. Involvement of the caudate nucleus suggests a possible biological mechanism of persuasion, i.e. the experts' context modulates evaluation of the object in terms of its perceived value, trust or risk-reward tradeoffs. By and large, our data suggest that experts (persuaders) modulate the activity in a set of brain regions involved in trustful behavior, learning and declarative memory encoding that probably enables effective persuasion. Our results thus start to uncover neuronal mechanisms underlying persuasion.

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Table 1. Attitude towards and memory for the objects that followed non-experts vs. objects that followed experts (means; SDs in brackets)

Context	Attitude (purchase intention, 0-100% scale)	Memory ($p_{hits} – p_{false\ alarms}$)
Non-experts	39.61 (9.7)	0.644 (0.16)
Experts	44.28 (12.5)	0.706 (0.17)
p	0.001	0.006

N=23

(SD) – standard deviation p – the observed significance level

Table 2. Significant activation clusters for subsequent attitude effect (favored vs. not favored objects)

Brain region	HEM	x	y	z	Nr of Voxels	Z (max)
Subsequent attitude effect (SAE)						
Middle frontal gyrus, BA10	R	33	61	8	168	-4.4
Anterior cingulate gyrus, BA 24	L/R	3	0	35	1098	-6.3
Caudate nucleus (Body)	R	10	-12	21	1066	-7.5
Insula, BA 13/precentral gyrus, BA 44	R	41	7	9	926	-5.1
Amygdala/parahippocampal gyrus, BA34,37	R	19	0	-12	300	-4.5
Ventral posterior thalamus	L	-16	-19	8	807	-5.0
Parahippocampal gyrus, BA 35	R	24	-24	-23	688	-7.3
Parahippocampal gyrus, BA 28	R	22	-22	-5	829	-6.5
Parahippocampal gyrus,BA36	L	-36	-23	-13	699	-5.4
Superior temporal gyrus, BA 13	L	-51	-39	17	830	-5.8
Middle occipital gyrus, BA19	R	37	-66	3	1331	-9.3
Lingual gyrus, BA 18	L	-11	-67	-2	1120	-7.4
Cuneus/posterior cingulate gyrus, BA30	R	10	-64	9	1313	-7.2

Favored objects are objects with high subsequent estimates of purchase incidence, not favored objects are objects with low estimates of purchase incidence.

Cluster threshold at a significance level of $P < 0.05$ were corrected for multiple comparisons using minimum cluster-size statistics the family-wise error rate or using small volume corrections (see Methods). Local maxima within these clusters are reported together with the number of voxels (Nr of Voxels). x, y, z are coordinates of the cluster center.

Table 3. Significant activation clusters for memory effects (hits vs. misses), celebrity expertise (experts vs. non experts) and celebrity attractiveness (attractive vs. unattractive)

Brain region	HEM	x	y	z	Nr Of Voxels	Z (max)
Subsequent memory effect (SME)						
Inferior frontal gyrus, BA 45, 46	L	-47	26	13	1550	7.2
Middle frontal gyrus, BA 46	R	39	29	18	738	8.0
Caudate nucleus (Body)	L	-9	11	9	1022	7.7
Medial globus pallidus	L	-8	-4	1	1088	6.8
Parahippocampal gyrus	L	-27	-9	-10	752	7.2
Posterior parahippocampal gyrus, BA 36,37	L	-27	-38	-11	1230	6.6
Parahippocampal gyrus, BA 36	R	24	-34	-17	1307	7.3
Parahippocampal gyrus /hippocampus	L	-29	-9	-12	548	6,6
Fusiform gyrus, BA 37	L	-42	-54	-10	1221	10.2
Middle temporal gyrus, middle occipital gyrus, BA 19	L	-30	-68	28	873	6.1
Celebrity expertise						
Precuneus BA 19	L	-34	-67	36	1108	5.8
Medial frontal gyrus, BA 6, cingulate gyrus, BA 24/31	L	-5	34	36	962	6.0
Anterior cingulate gyrus, BA 24	L	-4	13	48	642	7.2
Superior frontal gyrus, BA 10	L	-6	62	21	522	6.9
Inferior frontal gyrus, middle frontal gyrus BA 6/9	L	-40	6	30	690	5.5
Medial dorsal thalamus	L	-8	-14	6	660	6.2
Superior temporal gyrus, BA22/39	L	-41	-51	23	645	5.2
Celebrity attractiveness				no		

Table 4. Significant activation clusters for persuasive effects

Brain region	HEM	x	y	z	Nr of Voxels	Z (max)
Celebrity expertise x Subsequent attitude effect (SAE)						
Caudate nucleus (Body)	L	-12	11	8	702	5,9
Caudate nucleus (Body)	R	12	12	7	355	4.1
Superior frontal gyrus , BA 9	L	-14	50	25	688	4,5
Superior frontal gyrus, BA 10	R	9	66	18	553	3,9
Celebrity attractiveness x Subsequent attitude effect				no		
Celebrity expertise x Subsequent memory effect						
Parahippocampal gyrus/hippocampus	L	-30	-10	-8	603	3.8
Parahippocampal gyrus/hippocampus	R	38	-17	-7	332	4.7
Lingual gyrus, BA 18-19/fusiform gyrus	L	-17	-68	-5	797	5.12
Anterior cingulate gyrus, BA 24	L/R	4	-3	37	849	4.6

Figures

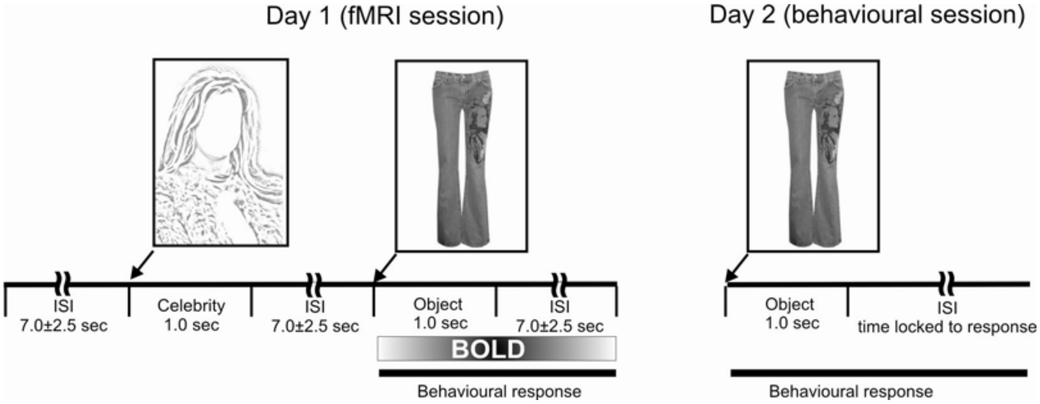

Figure 1. Trial structure. During each trial of the encoding session (Day 1), subjects were presented with the photo of a celebrity followed by the photo of an object (product). All stimuli were separated by varying interstimulus intervals (ISI). Subjects were instructed to indicate whether or not they see a link between the celebrity and the object. The gradient bar represents the time when BOLD signal was modelled for each trials. On day 2, recognition memory and attitude towards the object presented in two separate sessions were tested. Finally, familiarity, physical attractiveness and perceived expertise of celebrities were measured (this step is not depicted here).

A sketch of a celebrity and not a real photo as used in the study is presented in the figure due to potential copyright restrictions.

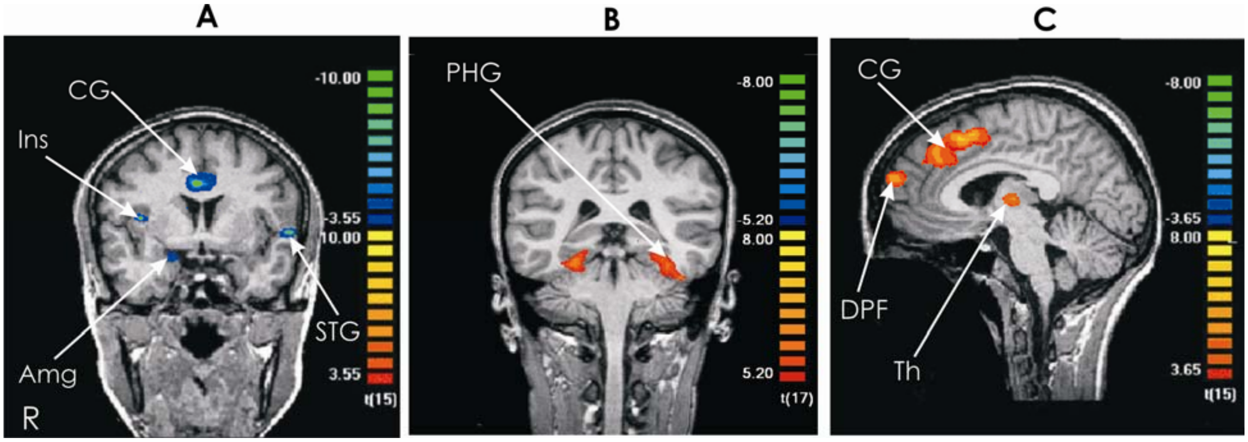

Figure 2. Main effects of attitudes (SAE), memory (SME) and celebrity expertise

(A) *Subsequent attitude effect* (SAE) on neural activation - the contrast of subsequently favored versus not favored objects (high vs. low estimates of purchase incidence); n = 16.

(B) *Subsequent memory effect* (SME) on neural activation (parahippocampal/fusiform gyrus) - the contrast between brain activity to later successfully remembered objects (hits) versus forgotten objects (misses); n = 18.

(C) Effect of perceived *celebrity expertise* on neural activation - the contrast of brain activity related to objects that followed experts versus objects that followed non-experts during the period following object encoding.

Amg – amygdala, CG- cingular gyrus, DPF – dorsal prefrontal cortex, PHG – parahippocampal/fusiform gyrus region, STG – superior temporal gyrus.region, Th - thalamus.

R – right hemisphere

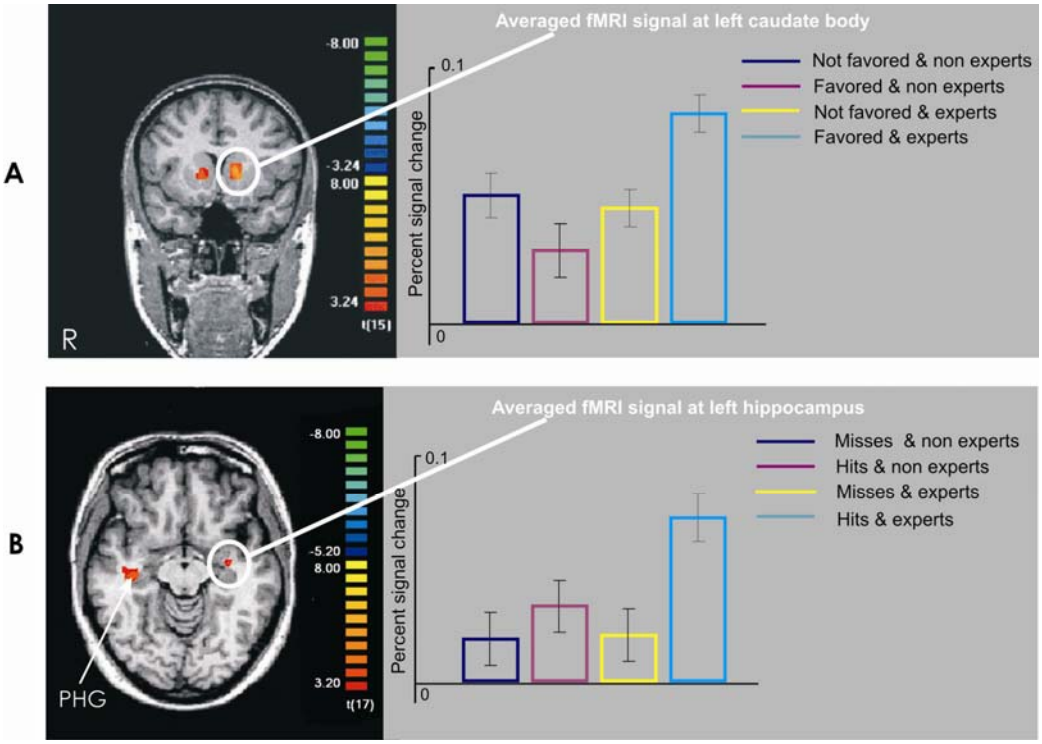

Figure 3. Persuasive expertise effects on attitudes and memory

(A) The interaction of perceived *celebrity expertise* with *subsequent attitude effect (SAE).*

The left panel depicts the interaction in the caudate nucleus. The right panel depicts the averaged fMRI signal for the left caudate nucleus cluster. The averaged fMRI signals for not favored objects (with low estimates of purchase incidence) that followed non-experts (dark blue), favored objects (with high estimates of purchase incidence) that followed non-experts (pink), not favored objects that followed experts (yellow) and favored objects that followed experts (light blue) are displayed. The averaged fMRI signals were calculated for all significant voxels within the cluster. The error bars depict standard errors of the mean. n = 16.

(B) The interaction of perceived *celebrity expertise* with *subsequent recognition memory (SME).*

The left panel depicts the interaction in the left hippocampus/parahippocampal cortex. The right panel depicts the fMRI signal for the left parahippocampal cluster. The averaged fMRI signals for subsequent misses (objects) that followed non-experts (dark blue), subsequent hits that followed non-experts (pink), subsequent misses that followed experts (yellow) and subsequent hits that followed experts (light blue) are displayed. PHG- parahippocampal cortex. n = 18.

Supplementary materials

I. Methods

Experimental Procedures

Subjects were selected using a specially designed questionnaire screening their interests and shopping behavior: the familiarity with celebrities, fashion magazines and TV programs was rated on 5-point unipolar Likert scales, from (1) “not at all” to (5) “very”. Only subjects that reported high familiarity with celebrities, fashion magazines and TV programs (mean ratings ≥3) and high interest in shopping (subjects spending ≥50 euros on cosmetics and/or clothing monthly) were selected for the study to homogenize group responses.

II. Results

Table S1 summarizes the behavioral persuasive memory effects. Overall subjects demonstrated better memory ($t(22, 1) = 2.7$, $p = 0.006$) for objects presented by experts (probability hits corrected by probability false alarm: 70.6%, SD=17) than by non-experts (64.4%, SD=16).

Table S2 represents mean estimates of purchase incidence for hits and misses. Previously (see Method section) we found that the correlation of the recognition memory performance with the attitude towards the object (estimates of purchase incidence) was extremely weak (r=0,053, tested across all items and subjects). Table S3 shows no difference in estimates of purchase incidence (p=0.77) for hits and misses and additionally indicate an independence of memory and attitude effects.

Subsequent memory effect (SME)

SME and SAE effects did not spatially overlap with the exception of the posterior portion of the parahippocampal gyrus. Thus, our results suggest rather different neural mechanisms of emotional evaluation and episodic memory that additionally indicates dissimilar nature of SME and SAE effects. The parahippocampal gyrus might be differentially involved in both emotional processing and episodic memory. The parahippocampal gyrus has been engaged by emotional stimuli (Blood et al., 1999; Koelsch et al., 2006) as well as during emotional states (e.g. (Damasio et al., 2000; Lane et al., 1997)). Moreover, previous studies have reported a parahippocampal engagement in processing of highly context-dependent information (Bar and Aminoff, 2003; Davachi, 2006). Given this evidence, it seems likely that the parahippocampal gyrus is involved in both the processing of emotional aspects of attitudes as well as information related to contextual encoding.

Table S1. Memory for the objects followed experts vs objects followed non-experts

	mean nr. of misses	mean nr. of uncertainty responses	mean nr. of hits	hits rate (%)	hits' probability	corrected hits' probability
non experts	16.92	2.20	51.43	72.9	0.729	0.644
experts	17.30	2.31	74.65	79.2	0.792	0.706

Corrected hits' probability - hits probability corrected by the probability of false alarms

N=23

Table S2. Hits and misses didn't differ in attitude. Mean estimates of purchase incidence averaged across hits and misses

subject	misses	Hits
1	34.4	30.9
2	50	39.3
3	37.1	41.1
4	62.3	66.9
5	27.9	30.5
6	46.2	49.9
7	25.6	29.3
8	52.5	53.6
9	35.8	33.5
10	50	51.9
11	56.9	47
12	51.1	53.5
13	42.2	39.7
14	23.5	28.8
15	34.2	30.2
16	50.3	49.5
17	43.8	48.4
18	44.7	36.9
19	32.3	35.3
20	42.8	46.6
21	28.4	32.7
22	44.3	42.9
23	44.4	49.1

Table S3. Additional statistical analysis testing the persuasive behavioral effects for pre-experimentally defined expertise and individual classification.

	Persuasive behavioral effects	
	Attitude	Memory
Individual classification (post scanning)	$t(22, 1) = 3.8$, $p = 0.001$	$t(22, 1) = 2.7$, $p = 0.006$
Pre-classification	$t(22, 1) = 2.1$, $p = 0.05$	$t(22, 1) = 1.9$, $p < 0.1$

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