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Brain and happy language: An activation likelihood estimation (ALE) meta-analytic review

ABSTRACT

The purpose of this study is to empirically find a connection between emotion and cognition that shows how they work in the decision-making process to clarify discussions on the role and effect of emotion in the decision making process. To verify the effect of emotion in the consumer decision making process, this study employs coordinate-based activation likelihood estimation (ALE) meta-analysis. The findings of this study show consistencies among an increasing number of studies investigating a consumer decision-making model based on the generic decision model, in which emotion influences cognition.

KEYWORDS: Emotion, Cognition, fMRI, and ALE meta-analysis

INTRODUCTION

In consumer research, both emotion and cognition play important roles in the consumer decision making process. Bettman et al (1998) propose a generic decision-making model that explains how a consumer makes a decision for purchasing a product. In this perspective, consumers rationally decide whether to purchase or not based on information that they gathered from external and internal sources. Alternative perspectives in consumer decision-making processes include the experiential point of view that recognizes consumers as feelers (emotional) as well as thinkers (rational) (Holbrook & Hirschman, 1982; Pine & Gilmore, 1999) and the behavioral influence perspective (Simonson & Winer, 1992; Sullivan, 2002) that focuses on consumer behaviors and the contingencies of the environment influencing the behaviors. In these perspectives of consumer decision making, emotion influences the congitive process that directly affects behaviors. For generic decision model, emotion is an internal source that affects cognition as a crucial factor of decision making. Thus, it is acknowledged that emotion essentially works as a key factor in the decision process.

Historically, neuroscience research on the relationship between emotion and cognition traces back to the early nineteenth century. At that time, scholars believed that a human brain has different and separate sections for emotion and cognition, referred to as the emotional brain and cognitive brain (Pessoa, 2008). They assumed that the brain has different sections that operate for specific purposes. This perspective has influenced current studies on emotion and cognition in the human brain (Pessoa, 2008). For example, Rolls (2005) looks at emotion as an institution that independently decides behaviors. This perspective indicates that emotions are considered as states caused by rewards and punishments. However, others prefer the view that emotions are involved in the conscious or unconscious evaluation of events, extended set of emotions including morality, and association with body control (Ekman, 1992; Damasio, 1999; Dolan, 2002; Haidt, 2003; Pessoa, 2008; Grimshaw et al, 2009).

Notwithstanding researches on emotion and cognition in the human brain, there have been few consumer research studies on the relationship between emotion and cognition using neurological images that show how the human brain works in terms of emotion and cognition. Thus, the purpose of this study is to empirically find a connection between emotion and cognition that shows how they work in the decision-making process. Especially, this study focuses on both language as a key component of cognition and happiness as a positive emotion because both are connected to each other, and this connection influences consumers' daily life. Thus, this study makes contributions by verifying the relevance of the connection between emotion and cognition in consumer decision-making processes through systematically reviewing the existing literature, especially by finding the focal brain regions activated by happiness as a positive emotion and language as a cognitive behavior in brain images through coordinate-based activation likelihood estimation (ALE) meta-analysis.

METHODS

Study selection

This study aims to find a connection between emotion (happiness) and cognition (language). For this purpose, this study performed a coordinate-based meta-analysis using the activation likelihood estimation (ALE) method (Turkeltaub et al, 2002; Eickhoff et al, 2009; 2012). Results from neuroimaging studies featuring experiments on happiness (positive) emotion and cognition (only language) were included. The following inclusion criteria were used to select the studies: 1) studies in peer-reviewed journals published in English, 2) use of fMRI neuroimaging technique, 3) studies featuring keywords “fMRI” or “functional magnetic resonance”, “happiness” or “positive affect”, and “language” or “linguistic cognition”, 4) studies providing or reporting [*x, y, z*] coordinates for happiness as an emotion and language as a cognitive behavior, and 5) to avoid bias, we excluded studies using anatomical region-of-interest (ROI) and interaction between emotion and language. In total, 13 fMRI studies (total number of foci = 98, total number of participants = 225) were involved in the final meta-analysis as shown in Table 1. Foci that were located outside the mask of gray matter by GingerALE 2.3.6 were excluded from all investigations.

ALE analysis

To investigate which brain regions were implicated in happiness and language, we employed the ALE meta-analytic method (Turkeltaub et al, 2002; Eickhoff et al, 2009) using GingerALE (http://brainmap.org/ale/index). There are several advantages in using this method: 1) it provides a quantitative and objective measure of the convergence of neuroimaging findings, thus it identifies activated brain region, 2) this identification empirically supports what studies are looking for, and 3) it finds gaps among studies. The ALE method extracts three-dimensional (Talairach or MNI) activation foci from relevant selected studies. These peak activation coordinates are displayed as a three-dimensional Gaussian distribution with an estimated full-width half maximization (FWHM) based on the selected studies. Probability distributions from an experiment are merged into a modelled activation (MA) map. Each MA map is combined into an ALE map on a voxel by voxel basis (Turkeltaub et al, 2012). The ALE map reflects the combined activation patterns of all experiments involved in the meta-analysis. To control for multiple comparisons, the ALE map was thresholded at a false discovery rate (FDR) of $p < 0.001$, incorrected. This study used a slightly more conservative cluster size threshold of 200 mm^3 than other ALE studies that have 100 mm^3 as a threshold (Cromheeke and Mueller, 2014). Lastly, ALE maps were overlaid onto an anatomical T1 weighted images in Talairach space and displayed with Mango software (http://www.ric.uthscsa.edu/mango).

Table 1. fMRI studies included in the meta-analysis

	First Author	Year	Sex (f/m)	Template	System	Threshold	Analysis
1	Acevedo	2014	10/8	MNI	3T	$p < 0.001$	SPM
2	Banks	2007	8/6	MNI	1.5T	$p < 0.001$	SPM

3	Berl	2014	26/31	MNI	3T	$p < 0.05$	SPM
4	Blair	2007	12/10	MNI	1.5T	$p < 0.005$	AFNI
5	Johnstone	2006	20/20	MNI	3T	$p < 0.05$	AFNI
6	Koelsch	2006	5/6	MNI	3T	$p < 0.005$	LIPSIA
7	McRae	2008	10/12	MNI	3T	$p < 0.001$	SPM
8	Nummenma a	2008	10/0	MNI	1.5T	$p < 0.001$	SPM
9	Ochsner	2002	15/0	MNI	3T	$p < 0.001$	SPM
10	Pereira	2011	5/9	MNI	1.5T	$p < 0.005$	FEAT/FSL
11	Tie	2014	8/6	MNI	3T	$p < 0.001$	SPM
12	Tu	2015	45	MNI	1.5T	$p < 0.05$	SPM
13	Viinikainen	2010	9/8	MNI	3T	$p < 0.001$	BrainVoyager

RESULTS

Emotion (positive and/or happy)

The main ALE analysis of emotion revealed 8 significant clusters, as shown in Table 2, with the largest cluster (volume = 7504 mm^3) located in the left medial and superior frontal gyrus (BA 6). The maximum ALE value of 3.79 was also observed in the left superior frontal gyrus (SFG: cluster volume = 7504 mm^3). Other significant clusters included the right insula (BA 13), cingulate gyrus (BA 32), the left middle temporal gyrus (BA 21), and the right model frontal gyrus (BA 10). In addition, these findings of this study in emotion regulations empirically supported the previous studies' findings (McRae et al, 2008). Remarkably, this study found that a cluster located in the left inferior frontal gyrus (BA 44) was observed in emotion (cluster volume = 1080 mm^3) because the left interior frontal gryus is generally known as the region (BA 44 and 45) controlling the process of generating language.

Table 2. ALE activation clusters associated with emotion									
Cluster	L/R	Anatomical label	BA	Volume (mm^3)	ALE value ($\times 10^{-3}$)	Peak coordinates *x*	*y*	*z*	N studies (foci)
1	L	Superior Frontal Gyrus	6	7504	3.79	-14	22	56	8(8)
		Medial Frontal Gyrus			3.34	-2	10	54	
2	R	Insula	13	1320	2.73	38	24	2	3(3)
		Inferior frontal Gyrus			2.65	44	26	4	
3	R	Cingulate Gyrus	32	1208	2.64	6	24	42	2(3)
			24		2.63	8	14	32	
4	L	Inferior Frontal Gyrus	44	1080	2.76	-52	16	14	2(2)
5	L	Claustrum		648	2.67	-28	20	4	3(3)
6	L	Middle Temporal Gyrus	21	320	2.53	-60	-38	-4	1(1)
7	R	Middle Frontal Gyrus	10	312	2.53	36	46	4	1(1)

8	R	Caudate		208	2.52	14	8	22	2(2)

N: number of studies reporting at least one activation peak; Coordinates: MNI; Space = mm^3, cubic millimeter, BA: Brodmann Area

Cognition (language)

The meta-analysis of cognition supports the existing literature that the language formulation area in the brain is located in the left posterior interior temporal region (Dien et al, 2008). The main ALE analysis of emotion reported 4 significant clusters, as shown in Table 3, with the largest cluster (volume = 2912 mm^3) located in the left inferior frontal gyrus and precentral gyrus (BA 9). The maximum ALE value of 1.87 was observed in the right middle frontal gyrus (cluster volume = 1920 mm^3). Other clusters are included in the left inferior frontal gyrus (BA 45) and the right caudate. The most significant cluster localized in the left inferior frontal gyrus and precentral gyrus was in BA 9, controlling short-term memory, verbal fluency, error detection, auditory verbal attention, and inductive reasoning. This area is also partially responsible for empathy and for processing pleasant and unpleasant emotional scenes (Farrow et al, 2001; Lane et al, 1997).

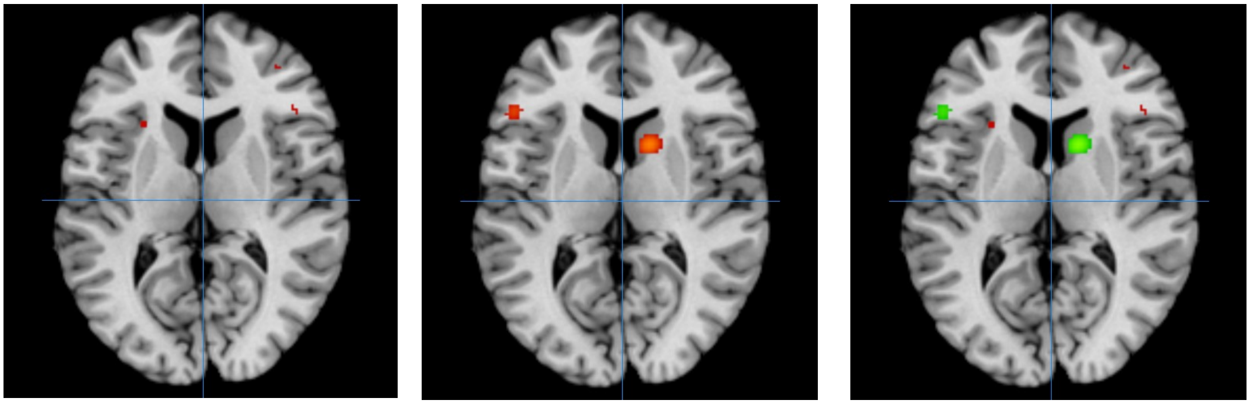
Table 3. ALE activation clusters associated with cognition

						Peak coordinates			
Cluster	L/R	Anatomical label	BA	Volume (mm^3)	ALE value ($\times 10^{-3}$)	*x*	*y*	*z*	N studies (foci)
1	L	Inferior Frontal Gyrus	9	2912	1.84	-44	14	28	2(4)
		Precentral Gyrus	9		1.73	-44	10	32	
2	R	Middle Frontal Gyrus	46	1920	1.87	50	22	24	2(3)
3	L	Inferior Frontal Gyrus	45	1736	1.65	-52	18	-2	2(3)
			45		1.50	-50	24	4	
4	R	Caudate		936	1.58	14	10	10	2(2)

N: number of studies reporting at least one activation peak; Coordinates: MNI; Space = mm^3, cubic millimeter, BA: Brodmann Area

DISUCSSION AND CONCLUSIONS

Figure 1. ALE foci for happiness and language



In summary, this meta-analysis sought to find consistencies among an increasing number of studies investigating a consumer decision-making model based on the generic decision model by Bettman et al. (1998), in which emotion influences cognition. While cognition is regulated in the left inferior frontal gyrus (BA 9), the right middle frontal gyrus (BA 46), and left inferior frontal gyrus (BA 45), emotion is mostly localized in the left superior and medial frontal gyrus (BA 6). However, interestingly, the left inferior frontal gyrus (BA 44), which is known to house the function that controls formulating language, is strongly associated with happiness as a positive emotion. Based on these findings, we can argue that there is a significant correlation between emotion and language. In particular, the findings of this study support the argument that emotion regulates language formulation. Thus, future works attempting to meaningfully understand a consumer decision-making are needed to find a meaningful pattern or a structural connectivity between emotions and cognition by mapping with brain activities of other components of both emotion (fear, sad, disgust, and anger) and cognition (memory, attention, judgment, and problem solving).

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