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The cortical processing of facial emotional expression is associated with social cognition skills and executive functioning: A preliminary study

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ABSTRACT

Several lines of experimental evidence support an association between facial processing and social cognition, but no direct link between cortical markers of facial processing and complex cognitive processes has been reported until now. In the current study, we tested the hypothesis that cortical electrophysiological markers for the processing of facial emotion are associated with individual differences in executive and social cognition skills. We tested for correlations between the amplitude of event-related potentials (N170) in a dual valence task and participants' scores on three neuropsychological assessments (general neuropsychology, executive functioning, and social cognition). N170 was modulated by the stimulus type (face versus word) and the valence of faces (positive versus negative). The neural source of N170 was estimated to be the fusiform gyrus. Robust correlations were found between neuropsychological markers and measures of facial processing. Social cognition skills (as measured by three tests: the Reading the Mind in the Eyes test, the Faux Pas test, and the Iowa Gambling Task) correlated with cortical measures of emotional discrimination. Executive functioning ability also correlated with the cortical discrimination of complex emotional stimuli. Our findings suggest that the cortical processing of facial emotional expression is associated with social cognition skills.

1. Introduction

Faces are among the most important visual stimuli for humans [17]. In the current study, we tested the hypothesis that cortical electrophysiological markers of the processing of facial emotion are associated with individual differences in complex social cognition skills. Face processing is critically important for many aspects of social interaction (see reviews [17,27]). Impairments in facial processing may be central to abnormal social cognition [15]. Furthermore, facial emotion processing has shown positive associations with information processing speed, executive function and working memory [18]. Indeed, Bruce and Young [4] have postulated that facial processing is related to high-level cognitive processes. This relationship would be explained by a higher order cognitive process in which the structural representation of the face is associated with semantic and cognitive information. Thus, facial processing may be also associated with important aspects of cognitive processing such as executive functions. Existing studies of healthy participants [11,12], participants with autism spectrum disorders [5], and participants with frontotemporal dementia [7] all suggest that facial processing is required for and related to different high-level social cognition skills. However, a possible association between the cortical markers of facial processing and neuropsychological markers of social cognition has not yet been proposed.

We measured cortical markers of face processing with an early event-related potential (ERP) component, referred to as the N170. This component shows a negative peak at approximately

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140–200 ms post-stimulus involved in the processing of faces [23]. The N170 component is sensitive to stimulus type (facial or other) [13,16,22] and is affected by emotional valence [3,29]. Moreover, the N170 amplitude can be modulated by interference [8] (e.g., two stimuli with opposing valences). Studies of brain topography have localized the source of the N170 to the fusiform gyrus (FG) [25]. The current study used a modified version of the dual valence task (DVT) [14,30] design with healthy participants. In the DVT, faces, words or simultaneous face–word stimuli are presented. Participants are asked to classify the stimuli according to their emotional valence. In order to relate cortical markers of face processing to social cognition and executive functions, a set of neuropsychological tests was included.

The most commonly used social cognition tasks test emotional inference, high level theory of mind processing and affective decision making. We hypothesised that the N170 would be associated with each of these three levels of social processing. First, we proposed emotional N170 would be associated with basic theory of mind (ToM), as measured by the Reading the Mind in the Eyes test (RMET) [2] because mental inference is determined by facial emotional content. Second, we expect the Faux Pas test [FPT], another ToM task, would be mediated by emotional and executive functions because the FPT involves dealing with a high number of cognitive and affective components [1]. Third, we proposed that decision making assessments with the Iowa Gambling Task [IGT] (especially the first of five blocks) would be associated with cortical emotional processing. Only the first block of the IGT can be consistently associated with ambiguity and influenced by emotional heuristics [6].

Based on these hypotheses, we predicted that higher performance on the social cognition tasks would correlate with greater discrimination of facial emotional valence and stimulus type as shown by the amplitude of the N170 component. Our second prediction was that higher performance on tasks of executive function would be associated with greater discrimination of emotional valence as shown by the amplitude of the N170 in response to simultaneous (face–word) stimuli.

2. Materials and methods

2.1. Participants

Twenty healthy participants (six females, 30.9 ± 2.3 years old, with 16.6 ± 0.6 years of formal education) completed the DVT. In a subsequent session, sixteen of the participants completed a neuropsychological battery that comprised tests of general neuropsychological functioning, executive functioning and social cognition. All participants completed the tasks voluntarily and signed an informed consent form in agreement with the Helsinki declaration. All experimental procedures were approved by the university's Ethics Committee.

2.2. Procedure

2.2.1. Dual valence task

Stimuli were displayed on a computer screen for 100 ms, and participants were instructed to categorize single (words or faces) or simultaneous (face–word) stimuli by valence, indicating whether the stimuli were 'positive' or 'negative' as quickly as possible. Incorrect responses were indicated with an 'X' in the center of the screen immediately after the response had been given (see [14] for more details). The trial sequence and block structure are described in the supplementary data.

2.2.2. Neuropsychological assessment

A subset of 16 participants (four females, mean age 32.5 ± 2.7, mean years in education 17.3 ± 0.7) received a battery of neuropsychological tests comprising tests of general neuropsychology (i.e., the Word Accentuation Test, the Rey Verbal Learning Test [RVLT] and the Wechsler Adult Intelligence Scale [WAIS]), executive functioning (i.e., the INECO Frontal Screening test [IFS], the Go/No Go test, the Backward Digit Span test [BDS], the Trail Making Test B [TMT-B], the Forward Digit Span test [FDS]), and social cognition (i.e., the FPT, the RMET and the IGT). These tests are described in more detail in the supplementary data.

EEG signals were sampled at 500 Hz from a Biosemi 128-channel system. All segments with eye movement contamination were removed from further analysis using an automated procedure. For each condition, dipole source models of the N170 component were estimated using an Automatic Relevance Determination (ARD) algorithm. Matlab software and EEGLab toolbox were used for offline processing and analysis of behavioral and ERP data. Regions of interest (ROIs) were used to analyze the scalp topography of the N170 mean amplitude. ERP recordings, source localization and data analysis methods are described in the supplementary data.

Accuracy, reaction times (RTs) and ERP waveforms were separately averaged for faces, words and simultaneous stimuli and analyzed using a repeated measures ANOVA with the following within-subject factors: 'stimulus type' (two levels: 'faces' and 'words') and 'valence' (two levels: 'positive' and 'negative'). For ERP data, the factor 'hemisphere' was considered (two levels: 'left' and 'right'). For all post hoc comparisons, Tukey's HSD test was performed.

To obtain correlations between ERPs and neuropsychological performance, DVT global scores of stimulus type discrimination, face valence, word valence and simultaneous valence (face–word stimuli) were calculated for accuracy, RTs and ERP results (see supplementary data). Global scores were tested for correlations with all of the neuropsychological tests (general neuropsychology, social cognition and executive functioning) using Spearman's rank and corrected for multiple comparisons using Tukey's HSD test. A significance level of $p < 0.05$ was used for all reported results.

3. Results

3.1. Behavioral measures

All participants performed with greater than 80% accuracy on all of the subtasks of the DVT (see supplementary material).

3.2. Neuropsychological assessment

All neuropsychological scores were within the expected normal ranges previously published in other reports (see supplementary material and Table 1, Section 1).

3.3. N170 source localization

The cortical source of the N170 component was localized to the FG anterior division (right hemisphere) for face stimuli. For word stimuli, N170 was localized to the border between the temporal pole and temporal fusiform cortex, anterior division (left hemisphere), with a second source in the temporal fusiform cortex, anterior division (right hemisphere). For simultaneous stimuli, N170 was localized to the temporal fusiform cortex, anterior division (right hemisphere) with a second source in the fusiform cortex, posterior division (left hemisphere; see Fig. 1D and supplementary material).

3.4. N170 stimulus type effects (faces versus words)

The comparison of ERPs for faces and words revealed no significant main effects when collapsed across both hemispheres (see

Table 1
Main results for neuropsychological assessments, ERPs and correlations.

	Mean	SD	Normal range[a]
(I) Performance on neuropsychological tests			
General neuropsychology			
Premorbid IQ (WAT-BA)	41.1	0.8	37–44
RVLT	52.4	1.7	48–75
Arithmetic (WAIS)	15.6	0.9	13-15
Forward Digit Span	7.1	0.2	6–8
Semantic fluency	24.9	1.4	18–28
Verbal fluency (COWAT),	22.7	1.6	15–25
Executive functions			
IFS	28.4	0.4	25–30
Backward Digit Span	5.7	0.6	4–7
TMT-B	61.6	4.1	55–120
Go/No Go	100%	0	94–100
Social cognition			
Reading the Mind in the Eyes	26.7	0.9	14–36
Faux Pas	19.44	0.2	17–20
IGT 1	−1.8	2	−2
IGT 2	3.5	1	8
IGT 3	2.8	1.7	10
IGT 4	5.4	1.5	8
IGT 5	5.7	1.4	8

	Mean amplitude in μV (SD)	Measures		p
		df	F	
(II) Dual valence task (ERPs)				
N170				
Faces versus words	RHF: −3.34 (1.11); LHW: −1.81 (0.77)	[1,19]	6.06	<0.05
Face valence	RHP: −3.97 (1.12); RHN: −2.70 (1.10)	[1,19]	66.10	<0.001
Simultaneous stimuli valence	PF: −0.91 (0.92); NF: −0.45 (0.92)	[1,19]	8.82	<0.01

	R
(III) Correlations[++]	
Correlations with behavioral results	
General neuropsychology tests	
Premorbid IQ (WAT-BA) versus overall RT	−0.52
RVLT versus accuracy	0.51
RVLT versus RT global score for stimulus interference	0.49
RVLT versus RT global score for valence discrimination	0.60
FDT versus RT global score for stimulus discrimination	0.54
FDT versus global score for valence discrimination	0.48
Correlations with ERPs	
Executive functions	
TMT-B versus N170 valence score in simultaneous stimuli	0.52
Social cognition	
'Reading the Mind in The Eyes' with N170 global scores for valence discrimination	0.57
Faux Pas versus N170 global scores for compatibility discrimination	0.56
IGT 1 versus N170 global scores for valence discrimination simultaneous stimuli	0.53

Notes: WAT-BA: word accentuation test-Buenos Aires; RVLT: Rey Verbal Learning Test; IFS: INECO Frontal Screening Test; TMT-B: Trial Making Test B; IGT: Iowa Gambling Task; RT: reaction time; RHF: right hemisphere faces; LHW: left hemispheres words; RHP: right hemisphere positive valence; RHN: right hemisphere negative valence; PF: positive face valence; NF: negative face valence.

[a] See supplementary material for normal ranges' references and tests descriptions.

[++] All correlations presented in the table are significant at $p < 0.05$, HSD Tukey correction.

Fig. 1A and B). In accordance with previous studies that found opposite lateralization of faces and words [24], we found a significant interaction between stimulus type and hemisphere ($F[1,20] = 6.06$, $p < 0.05$). Post hoc comparisons (MS = 1.82, df = 20) revealed that the N170 discriminated stimulus type only within the right hemisphere (right hemisphere: -3.34 ± 1.11 μV for faces and -1.81 ± 0.77 μV for words, $p < 0.05$; left hemisphere: -2.39 ± 0.90 μV for faces and -2.31 ± 0.72 μV for words, $p = 0.99$) (Table 1, Section 2).

3.5. N170 face valence effects

A significant effect of valence was found ($F[1,20] = 66,10$, $p < 0.01$), which reflects an increased N170 amplitude in response to positive faces as compared to negative faces (-3.35 ± 0.96 μV and -2.38 ± 0.95 μV, respectively). There was no significant main effect of hemisphere ($F[1,20] = 2.056$, $p = 0.167$) and no significant interaction between face valence and hemisphere ($F[1,20] = 11.01$, $p < 0.01$). Post hoc comparisons (MS = 0.16, df = 20) revealed that face valence was better discriminated by the N170 in the right hemisphere (positive: $-3.97 + 1.12$; negative: $-2.70 + 1.10$, $p < 0.001$) than in the left hemisphere (positive: $-2.7 + 0.81$ μV; negative: $-2.04 + 0.89$, $p < 0.05$). See Table 1 (Section 2) and Fig. 1A.

3.6. N170 word valence effects

N170 was not modulated by word valence ($F[1,20] = 0.55$, $p = 0.47$). The interaction between word valence and hemisphere was not significant ($F[1,20] = 2.84$, $p = 0.11$).

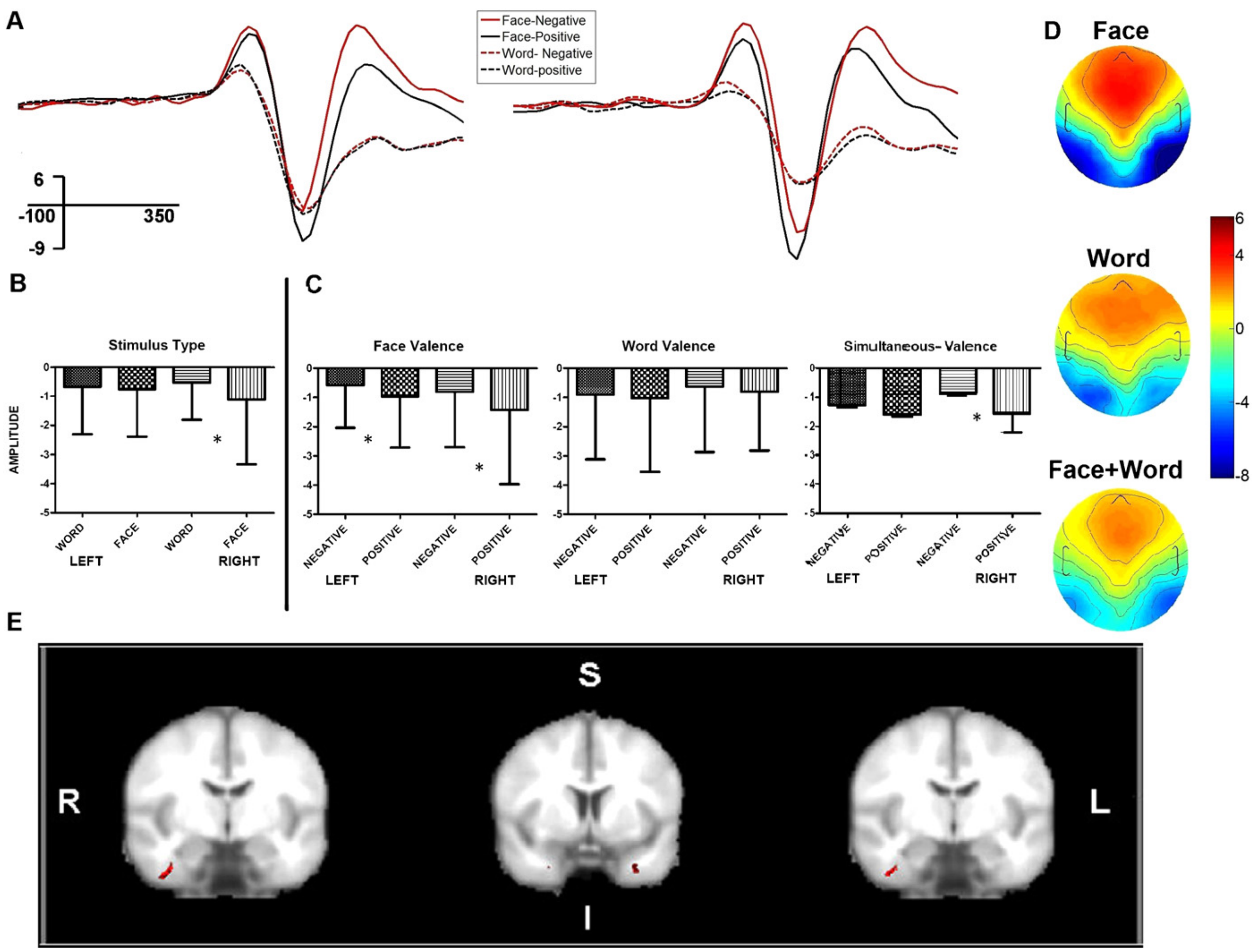

Fig. 1. ERP data and source localization. (A) Left and right hemisphere ERPs for face and word stimuli. (B) Mean N170 amplitudes for face versus word stimuli in both hemispheres. (C) Mean N170 amplitudes for valence effects of face, word and both stimuli in both hemispheres (bars indicate SD). (D) Scalp ERPs for face, word and simultaneous stimuli. In each graph, asterisks (*) indicate significant differences. (E) Coronal sections of the estimated sources of the N170 component in response to face stimuli (left), word stimuli (middle) and simultaneous stimuli (right). R: right; L: left; S: superior; I: inferior.

3.7. N170 simultaneous stimuli valence effects

The N170 discriminated the face valence of simultaneous stimuli ($F[1,19] = 8.82$, $p < 0.01$), with a mean of -0.91 ($\pm 0.92\ \mu$V SD) and -0.457 ($\pm 0.920\ \mu$V SD) for positive and negative faces, respectively (the N170 response was greater for positive faces than negative faces, as was the case for face stimuli alone). There were no significant main effect differences between the hemispheres for simultaneous stimuli ($F[1,19] = 0.08$, $p = 0.78$), but there was a significant interaction between valence and hemisphere ($F[1,19] = 4.88$, $p < 0.05$). Post hoc comparisons (MS = 0.27, df = 19) revealed that face valence was discriminated within the right hemisphere when presented simultaneously with words ($p < 0.01$ for right hemisphere and $p = 0.65$ for left hemisphere).

Fig. 1 summarizes the main effects. In brief, these results confirm that the N170 component was correctly estimated.

3.8. Correlations

3.8.1. General neuropsychology

3.8.1.1. Behavioral measures. Correlations were found between general memory (as measured by the RVLT) and overall accuracy ($r = 0.51$), general memory and RTs global score for stimulus discrimination (RTs face–RTs word) ($r = 0.39$), general memory and RTs global score for simultaneous stimulus valence (RTs positive/RTs negative) ($r = 0.49$), and general memory and RTs global score for valence discrimination (RTs positive–RTs negative) ($r = 0.60$). Working memory (as measured by the Forward Digit Span Test) correlated with the RTs global score for stimulus discrimination (RTs face/RTs word) ($r = 0.54$) and the RTs global score for valence discrimination RTs (RTs positive/RTs negative) ($r = 0.48$).

3.8.2. Executive functioning

3.8.2.1. Behavioral measures. Scores of executive functions (IFS) correlated with the RTs global scores for stimulus discrimination (RTs face–RTs word) ($r = 0.54$) and with the RTs global scores for face valence discrimination (RTs positive–RTs negative) ($r = 0.54$).

3.8.2.2. ERP measures. Scores on the Trial Making Test B correlated positively with the N170 global scores for valence discrimination in simultaneous stimuli ($r = 0.52$).

3.8.3. Social cognition

3.8.3.1. ERP measures. Scores from the IGT block 1 correlated significantly with the ERP global scores for valence discrimination in simultaneous stimuli ($r = 0.53$). Scores on the RMET correlated significantly with the N170 global scores for face valence discrimination (positive–negative) ($r = 0.57$). Scores on the FPT correlated with the N170 global scores for valence discrimination in simultaneous stimuli ($r = 0.56$). Correlation results are summarized in Table 1 (Section 3).

4. Discussion

The aim of this study was to explore the association between the processing of facial emotion and complex social abilities. Our main finding was that the early processing of facial emotions was associated with patterns of individual neuropsychological performance. Specifically, modulation of the N170 component in response to facial emotions was associated with scores on measures of social cognition.

4.1. Dual valence task: behavioral measures and general neuropsychology

The results from tests of general neuropsychology suggested that both general and working memory functioning were associated with RT measures for stimulus type and face valence discrimination. These findings are consistent with previous research [11] and suggest that early brain activity that discriminates stimuli and emotional valence is partially related to mnemonic skills. In this study, the mapping of valence to a response was arbitrary (a specific key on the keyboard for each valence); this finding may reflect the ability to robustly establish this temporary arbitrary mapping.

4.2. Association of N170 with neuropsychological scores

Regarding executive functioning, TMT-B correlated positively with the N170 valence discrimination in simultaneous stimuli. This result suggests that there is an association between simultaneous task segregation and the physiological segregation needed to focus on a face and ignore a word. Moreover, TMT-B is a test that is sensitive to frontal lobe damage [9], suggesting that the discrimination by early ERPs of face valence in the presence of interfering stimuli, which occurs in many cognitive processes that require executive control, depends on frontal lobe executive functioning.

In terms of the importance of social cognition, we generated three important findings. First, scores on a measure of theory of mind related to emotional inference (RMET) correlated significantly with the N170 global scores for valence discrimination (positive/negative). This result suggests that the more basic ToM processes (e.g., emotional inference) are supported, at least in part, by early brain activity that is sensitive to facial emotional valence. Second, scores on the Faux Pas test (FPT) correlated with N170 compatibility discrimination. The compatibility effect may be associated with the cognitive ability to make inferences about others' mental states at a more complex level. Additionally, the FPT involves dealing with a high number of cognitive and affective components, including contextual cues and inferences about others' mental states [21], as compared to the RMET [19,26]. The pattern of association we observed for the two tests fits well with this distinction in complexity (the FPT as associated with more complex ToM processes and the RMET with more basic emotional stages).

Finally, we found that only the first block of the IGT correlated significantly with the ERPs of valence discrimination for simultaneous stimuli. This first block consists of an exploration of the cards used in the task. It reflects decision making under total uncertainty (because participants are unaware of the cards' properties) and is related to emotional decision making. This association between emotional processing and the first IGT block is relevant because the subsequent blocks of the IGT cannot be considered to reflect decision making under conditions of ambiguity, but rather, they reflect decision making under conditions of risk [6]. Research that was conducted using participants with neuropsychiatric diagnoses also supports this distinction [28]. Our current findings suggest that basic emotional discrimination is related to an implicit and emotional ability to make decisions in an ambiguous context.

It has previously been hypothesised that the processing of facial emotion is intertwined with complex social skills [10] and executive functioning [20]. Consistent with these findings, our data suggest that there is an association between cortical markers of facial processing and performance on tasks of social cognition (i.e., ToM and IGT). In addition, an association was observed between the N170 response and the subject's performance on tests of executive functioning (simultaneous task segregation). However, given the small sample size in the current study, our results should be interpreted with caution.

Conflict of interest

None to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.neulet.2011.09.062.

References

[1] F.S. Ahmed, L. Stephen Miller, Executive function mechanisms of theory of mind, J. Autism Dev. Disord. 41 (2011) 667–678.
[2] S. Baron-Cohen, S. Wheelwright, J. Hill, Y. Raste, I. Plumb, The Reading the Mind in the Eyes Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism, J. Child Psychol. Psychiatry 42 (2001) 241–325.
[3] M. Batty, M.J. Taylor, Early processing of the six basic facial emotional expressions, Brain Res. Cogn. Brain Res. 17 (2003) 613–620.
[4] V. Bruce, A. Young, Understanding face recognition, Br. J. Psychol. 77 (1986) 305–327.
[5] T.F. Clark, P. Winkielman, D.N. McIntosh, Autism and the extraction of emotion from briefly presented facial expressions: stumbling at the first step of empathy, Emotion 8 (2008) 803–809.
[6] D.B. Dunn, T. Dalgleish, A.D. Lawrence, The somatic marker hypothesis: a critical evaluation, Neurosci. Biobehav. Rev. 30 (2006) 239–271.
[7] D. Fernandez-Duque, S.E. Black, Impaired recognition of negative facial emotions in patients with frontotemporal dementia, Neuropsychologia 43 (2005) 1673–1687.
[8] S. Fruhholz, T. Fehr, M. Herrmann, Early and late temporo-spatial effects of contextual interference during perception of facial affect, Int. J. Psychophysiol. 74 (2009) 1–13.
[9] P.A. Gouveia, S.M. Brucki, S.M. Malheiros, O. Bueno, Disorders in planning and strategy application in frontal lobe lesion patients, Brain Cogn. 63 (2007) 240–246.
[10] T. Grossmann, The development of emotion perception in face and voice during infancy, Restor. Neurol. Neurosci. 28 (2010) 219–236.
[11] G. Herzmann, O. Kunina, W. Sommer, O. Wilhelm, Individual differences in face cognition: brain–behavior relationships, J. Cogn. Neurosci. 22 (2010) 571–589.
[12] C.M. Hileman, H. Henderson, P. Mundy, L. Newell, M. Jaime, Developmental and individual differences on the P1 and N170 ERP components in children with and without autism, Dev. Neuropsychol. 36 (2011) 214–236.
[13] A. Ibanez, E. Gleichgerrcht, E. Hurtado, R. Gonzalez, A. Haye, F. Manes, Early neural markers of implicit attitudes: N170 modulated by intergroup and evaluative contexts in IAT, Front. Hum. Neurosci. 4 (2010) 188.
[14] A. Ibáñez, A. Petroni, H. Urquina, F. Torrente, T. Torralva, E. Hurtado, R. Guex, A. Blenkmann, L. Beltrachini, C. Muravchik, S. Baez, M. Cetkovich, M. Sigman, A. Lischinsky, F. Manes, Cortical deficits in emotion processing for faces in adults with ADHD: its relation to social cognition and executive functioning, Soc. Neurosci. 2011, doi:10.1080/17470919.2011.620769.
[15] R. Itier, M. Batty, Neural bases of eye and gaze processing: the core of social cognition, Neurosci. Biobehav. Rev. 33 (2009) 843–863.
[16] R. Itier, M.J. Taylor, Source analysis of the N170 to faces and objects, Neuroreport 15 (2004) 1261–1265.
[17] D.A. Leopold, G. Rhodes, A comparative view of face perception, J. Comp. Psychol. 124 (2010) 233–251.
[18] D. Mathersul, D.M. Palmer, R.C. Gur, R.E. Gur, N. Cooper, E. Gordon, L.M. Williams, Explicit identification and implicit recognition of facial emotions:

II. Core domains and relationships with general cognition, J. Clin. Exp. Neuropsychol. 31 (2009) 278–291.
[19] K.N. Ochsner, The social-emotional processing stream: five core constructs and their translational potential for schizophrenia and beyond, Biol. Psychiatry 64 (2008) 48–61.
[20] L. Pessoa, How do emotion and motivation direct executive control? Trends Cogn. Sci. 13 (2009) 160–166.
[21] R. Riveros, F. Manes, E. Hurtado, M. Escobar, M. Martin Reyes, M. Cetkovich, A. Ibanez, Context-sensitive social cognition is impaired in schizophrenic patients and their healthy relatives, Schizophr. Res. 116 (2010) 297–298.
[22] B. Rossion, I. Gauthier, V. Goffaux, M.J. Tarr, M. Crommelinck, Expertise training with novel objects leads to left-lateralized facelike electrophysiological responses, Psychol. Sci. 13 (2002) 250–257.
[23] B. Rossion, C. Jacques, Does physical interstimulus variance account for early electrophysiological face sensitive responses in the human brain? Ten lessons on the N170, Neuroimage 39 (2008) 1959–1979.
[24] B. Rossion, C.A. Joyce, G.W. Cottrell, M.J. Tarr, Early lateralization and orientation tuning for face, word, and object processing in the visual cortex, Neuroimage 20 (2003) 1609–1624.
[25] B. Sadeh, Event-related potential and functional MRI measures of face-selectivity are highly correlated: a simultaneous ERP-fMRI investigation, Hum. Brain Mapp. 31 (2010) 1490–1501.
[26] V.E. Stone, S. Baron-Cohen, R.T. Knight, Frontal lobe contributions to theory of mind, J. Cogn. Neurosci. 10 (1998) 640–656.
[27] A. Tate, H. Fischer, A.E. Leigh, J.M. Kendrick, Behavioural and neurophysiological evidence for face identity and face emotion processing in animals, Philos. Trans. R. Soc. Lond. B: Biol. Sci. 361 (2006) 2155–2172.
[28] E. Gleichgerrcht, A. Ibanez, M. Roca, T. Torralva, F. Manes, Decision Making Cognition in Neurodegenerative Diseases, Nat. Rev. Neurol. 6 (2010) 611–623.
[29] P. Vuilleumier, G. Pourtois, Distributed and interactive brain mechanisms during emotion face perception: evidence from functional neuroimaging, Neuropsychologia 45 (2007) 174–194.
[30] A. Ibáñez, E. Hurtado, R. Riveros, H. Urquina, J. Cardona, A. Petroni, F.A. Lobos-Infante, J. Barutta, S. Baez, F. Manes, Facial and semantic emotional interference: a pilot study on the behavioral and cortical responses to the Dual Valence Association Task, Behav. Brain. Funct. 13 (7) (2011) 8.