Research in Autism Spectrum Disorders 5 (2011) 775–783

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

Journal homepage: http://ees.elsevier.com/RASD/default.asp

# Neutral versus emotional human stimuli processing in children with pervasive developmental disorders not otherwise specified

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ARTICLE INFO

*Article history:*
Received 31 August 2010
Accepted 7 September 2010

*Keywords:*
PDD-NOS
Autism
Children
Human stimuli
Neutral
Emotional
Visual
Auditory
Multimodal processing

ABSTRACT

Pervasive developmental disorder not otherwise specified (PDD-NOS) represents up to two-thirds of autism spectrum disorders; however, it is usually described in terms of the symptoms not shared by autism. The study explores processing of neutral and emotional human stimuli (by auditory, visual and multimodal channels) in children with PDD-NOS ($n = 10$) compared to typically developing children ($n = 35$). The neutral human stimuli consisted of faces and common first names. The emotional human stimuli consisted of happy, sad, angry, and neutral faces and vocalizations. The results confirmed previous findings and led to others. The PDD-NOS group (a) accurately processed neutral human stimuli; (b) had difficulty processing emotional stimuli in general and more easily identified happy compared to angry or neutral faces and vocalizations; (c) had a strong discrepancy between emotional and neutral human stimuli processing; (d) used the multimodal channel to compensate for unimodal deficits, especially for angry faces; and (e) was strongly heterogeneous.



## 1. Introduction

Some children have trouble with social interaction, communication and/or rigid behavior patterns that do not fulfill criteria for autism. Their pathology is usually diagnosed as pervasive developmental disorder not otherwise specified (PDD-NOS; APA, 1994). Similar to autism, Rett syndrome, Asperger syndrome and childhood disintegrative disorder, the DSM-IV classifies PDD-NOS as a subtype of PDD. The prevalence of PDD-NOS is higher than autism (20.8 PDD-NOS/10,000 vs. six children with autism/10,000; Fombonne, 2005), but its associated literature is approximately 100× smaller based on an EBSCO bibliographic estimation. Two factors explain this difference. First, PDD-NOS is a vague category, mainly defined by exclusion criteria related to autism (Lord et\ al., 2006; Volkmar, Paul, Klin, Cohen, & Hoboken, 2005). Second, several studies have pointed out that the diagnosis stability over time was significantly weaker in PDD-NOS compared to autism (Charman et al., 2005; Cox et al., 1999; Moore & Goodson, 2003; Stone et al., 1999). Rondeau et al. (in press) confirmed this assumption using a meta-analytic approach. Thus, most studies on autism spectrum disorder (ASD) do not specify whether participants are especially high-functioning people with autism, Asperger Syndrome (Rondeau et al., in press) or PDD-NOS (de Bruin, de Nijs, Verheij, Hartman, & Ferdinand, 2007). Conversely, the Utrecht Group (based on proposals from the Yale Child Study

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doi:10.1016/j.rasd.2010.09.005

Center) uncovered a set of syndrome patterns in children with PDD-NOS that appear as a specific group called ‘‘multiple complex developmental disorder’’. This subgroup is defined by the following: (a) important social and communication difficulties; (b) emotional dysfunction; (c) cognitive troubles; and (d) a risk of schizophrenia in adolescence (Buitelaar & Van der Gaag, 1998; de Bruin et al., 2007; Van der Gaag et al., 1995). Using a complementary perspective, the present study focuses on the PDD-NOS category to characterize some of its components. We used an original methodology that considers human stimuli processing in neutral and emotional conditions using visual, auditory and cross-modal channels.

Social cognition is the ability to detect cognitive, meta-cognitive and emotional processes within human interactions, involves consciousness of the self and others, and combines all the skills necessary to understand and react to emotions, especially those transmitted by faces (Grossmann, Striano, & Friederici, 2006). Social cognition includes (but is not limited to) initiating social contact with people through eye contact and language. It also includes looking at and remembering the faces of others, being empathetic and Theory of Mind (Baron-Cohen, 1991; Baron-Cohen et al., 2000).

In humans, emotion identification requires audition (e.g., vocalization, prosody and semantic features) and vision (e.g., facial expressions). Because the brain integrates information from different modalities to produce accurate and meaningful representations unobtainable from either modality taken in isolation (Molhom, Ritter, & Lakatos, 2002; Ross, Prodan, & Monnot, 2007), multimodal connections optimizes visual or auditory processing in normal and pathological people (Collignon et al., 2008). Object identification is more accurate in audiovisual than separate auditory or visual conditions (Giard & Peronnet, 1999). With regard to emotion, a similar multimodal facilitating effect has been observed (Campanella & Belin, 2007). Multimodal integration increases the speed and accuracy of emotional recognition (Collignon et al., 2008; Dolan, Morris, & de Gelder, 2001; Kreifelts, Ethofer, Grodd, Erb, & Wildgruber, 2007). Thus, remediation protocols should reinforce multimodal processing to compensate for deficiencies in sensation or perception, especially in children with autism (Massaro & Bosseler, 2006; Williams et al., 2004).

Social interaction and emotion-processing difficulties are predominant in ASD (Serra, Minderaa, van Geert, & Jackson, 1999). Children with autism have difficulty identifying emotional states, although they correctly recognize neutral human stimuli (Hobson, 1993; Hobson, Ouston & Lee, 1988). This finding suggests that children with autism have primary and specific deficits in emotional processing.

The few studies on children with PDD-NOS showed that these participants have difficulties in comprehending and interpreting social information (Gillberg, 1991; Serra, Loth, van Geert, Hurkens, & Minderaa, 2002). Focusing on visual perception, De Wit, Falck-Ytter, and von Hofsten (2008) noted that children with PDD and PDD-NOS spent less time looking at emotional faces than normal children. These children also looked less at facial features that transmit emotional (i.e., eyes, nose, and mouth). Because salient combined ‘‘action units’’ of low, medium or high levels support facial emotions (Ekman & Friesen, 1976), the greater the fixation on the mouth, the more severe the social deficit (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Merin, Young, Ozonoff, & Rogers, 2007; Pelphrey & Sasson, 2002).

Sicotte and Stemberger (1999) showed that people with autism had more difficulty processing facial emotion than people with PDD-NOS. Thus, social cognition studies delineate the emotion processing difficulties in the different clinical populations and are able to specify the emotional disorders that interfere with attention (Lee & Ousley, 2006). Emotion can disrupt attention by directing it toward (vigilance) or away (avoidance) from emotional stimuli. In the context of anxiety disorders, the influence of emotional threat on attention is called ‘‘threat-related attention bias’’ in which the presence of specific features produces a change in attention location (Monk et al., 2006; Pine et al., 2005). However, there is uncertainty regarding the direction of attention to threatening faces. Some studies have found vigilance effects, and others have found avoidance effects. These conflicting results may be due to the task paradigm, the nature of the stimuli, stimulus duration, and heterogeneity in the clinical population (Stirling, Eley & Clark, 2006).

We aimed to identify specific psychological patterns in children with PDD-NOS by comparing them to typically developing children. To characterize emotional processing in children with PDD-NOS, we contrasted neutral with emotional human stimuli (e.g., happy, angry, sad and neutral) across different perceptual modalities (visual, auditory and multimodal). We used two experimental paradigms; to avoid verbal production, we required that children (1) recognize targeted faces, first names and face/first name pairs among distracters; and (2) match facial or vocal emotions expressed by two people and judge whether a voice and a face expressed congruent emotions. Thus, children had to judge similarities and dissimilarities between visual, auditory and multimodal neutral human stimuli, and match emotion expressions using visual, auditory and multimodal channels.

Consistent with previous studies, we hypothesized that children with PDD-NOS would accurately process neutral human stimuli but have difficulty processing emotional information, in particular visually. In addition, we hypothesized that children with PDD-NOS would compensate for visual/auditory discrepancies using multimodal processing.

## 2. Method

### 2.1. Participants

A total of 10 children with PDD-NOS (9 males and 1 female) and 35 typically developing children (30 males and 5 females) participated in this study. Table 1 summarizes the socio-demographic and clinical characteristics of the participants.

Three trained child-psychiatrists clinically assessed the children with PDD-NOS (age range = 7–13 years, $M = 9.6$, SD = 1.7). We based a PPD-NOS diagnosis on the Diagnostic and Statistical Manual of Mental Disorders-Fourth Edition

**Table 1**
Group characteristics.

| | PDD-NOS group ($n = 10$) Mean (SD) | Control group ($n = 35$) Mean (SD) |
|---|---|---|
| Age (year) | 9.6 (1.7) | 8.4 (1.8) |
| Male–female | 9–1 | 30–5 |
| ADI-R scores, current | | |
| Social impairment | 12.7 (7.8) | – |
| Communication | 8.5 (6.4) | – |
| Repetitive interest | 2.0 (1.6) | – |
| Total score | 25.7 (15.4) | – |
| CARS scores | 22.3 (5.4) | |

*Note*: PDD-NOS, pervasive developmental disorder not otherwise specified; ADI-R, autism diagnostic interview-revised; CARS, childhood autism rating scale.

criteria (DSM-IV; APA, 1994), the Autism Diagnostic Interview-Revised (ADI-R) and the Child Autism Rating Scale (CARS). These children also fulfilled diagnostic criteria for multiple complex developmental disorders (Buitelaar & Van der Gaag, 1998; Van der Gaag et al., 1995), which we used to limit PDD-NOS heterogeneity and improve its stability over time (Rondeau et al., in press). All participants were cognitively assessed using the Wechsler Intelligence Scale for Children (WISC III; Wechsler, 1994 or WISC IV; Wechsler, 2005). Although most patients obtained heterogeneous scales, none had a score below 70.

We recruited children with PPD-NOS via the Child and Adolescent Psychiatry departments at Pitié-Salpêtière Hospital and the Université Pierre-et-Marie-Curie, Paris, France. Each participant was individually matched with 4 healthy typically developing children aged 6–12 years ($M = 8.4$ years; SD = 1.8) recruited via local primary schools.

### 2.2. Stimuli

This material included visual and auditory, neutral and emotional stimuli. The neutral visual stimuli included 36 pictures of neutral faces (18 female, 18 male), and the neutral auditory stimuli included 36 spoken first names (18 female, 18 male). We extracted black and white neutral facial images, resized to 450 pixels in height and presented on a gray background, from the CAL/PAL face database (Minear & Park, 2004). The auditory stimuli were common disyllabic first names spoken by a feminine voice using Adobe Audition.

Emotional visual stimuli included 24 pictures of happy, angry, sad or neutral faces taken from the Ekman series (Ekman & Friesen, 1976). The emotional auditory stimuli included 24 happy, angry, sad and neutral prosodic vocalizations (e.g., laughs, angry screams, cries and throat clearings) taken from the standardized Montreal Affective Voices Database designed for research on auditory emotional processing (Belin, Fillion-Bilodeau & Gosselin, 2008).

### 2.3. Procedures

Testing commenced following the procurement of parental consent and child assent. We assessed participants on their capacity to (a) recognize neutral stimuli (neutral tasks) in a visual (faces), auditory (first names) and cross-modal task (simultaneously presented faces and first names) and (b) discriminate emotional stimuli (emotional tasks) from visual (facial emotion), voice (vocal emotion) and multimodal cues (simultaneously presented vocal and facial cues). We created the experimental protocol using E-Prime 1.1 (Psychology Software Tools, Inc., Pittsburgh, PA). Children sat approximately 70 cm from a 17-in. monitor. We individually tested participants in a single session for approximately 45 min. Neutral and emotional tasks were counterbalanced across participants and preceded by a training phase that familiarized children with the task.

### 2.4. Neutral tasks

During each of the three tasks, we presented eight sequences of stimuli. After displaying a black screen for 3000 ms children briefly observed a target stimulus (2000 ms for visual, 600 ms for auditory; Fig. 1A). The target appeared two or three times within three or four distracters. There were 20 matched targets in each task. Children determined whether – in each sequence – the stimuli (a face, a first name, or a pair face/first name) matched the target by pressing the "S" or the "L" keys of a French keyboard, respectively. These keys were identified by two colored labels (green for "same" and red for "different") and were counterbalanced across participants.

### 2.5. Emotional tasks

We assessed participants' capacity to recognize emotions from visual, vocal or multimodal cues (Fig. 1B). We presented pairs of emotional stimuli (e.g., faces, voices and multimodal face/voice stimuli); children had to decide whether the pairs expressed the same emotion (happiness, angriness, sadness, neutrality) or not by pressing the green "S" or the red "L" keys,

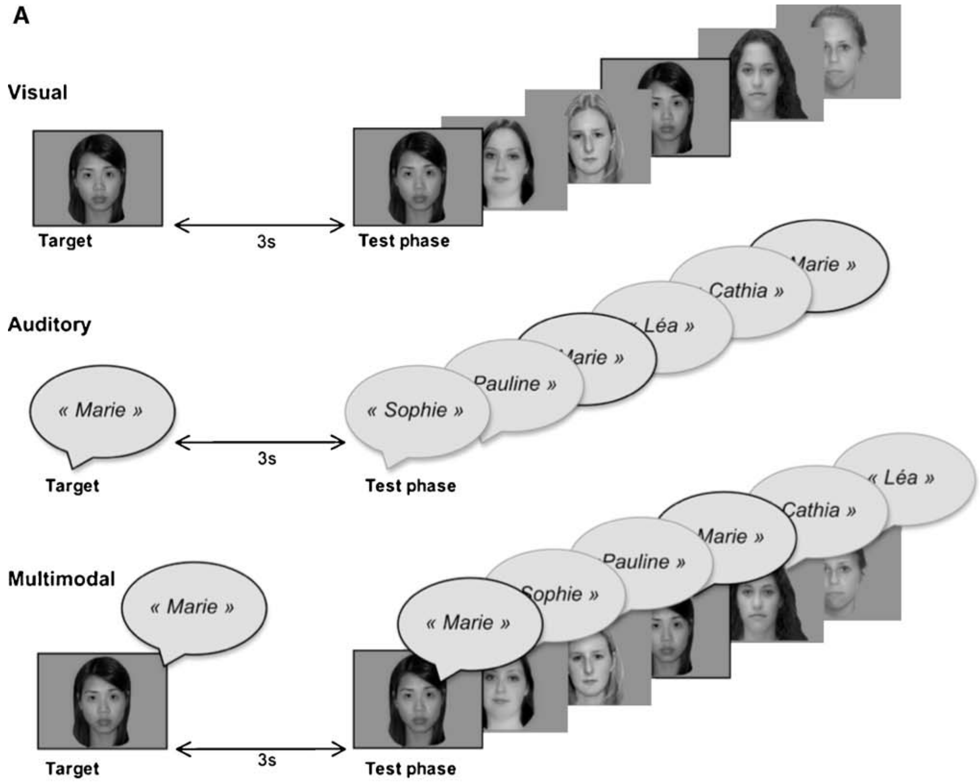


**Fig. 1.** An illustration of the two paradigms: (A) neutral paradigm with a visual task (faces), an auditory task (first names) and a cross-modal task (simultaneous faces and first names); (B) emotional paradigm with pairs of visual stimuli (facial emotion), pairs of auditory stimuli (vocal emotion) and pairs of visual/auditory stimuli (simultaneous facial and vocal emotion).

respectively. Again, we counterbalanced the keys across participants. We selected happy, angry and sad faces because they are the easiest emotions to recognize for children. Fear, surprise and disgust are more ambiguous (Gosselin, 1995). The visual task matched pairs of emotional faces, the auditory task matched pairs of emotional voices, and the cross-modal task matched pairs of emotional face and voice. There were 24 trials in each task (12 matching trials and 12 non-matching trials).

### 2.6. Statistical analyses

Because of the small sample size, we compared performances using non-parametric tests. The Mann–Whitney *U* test was used to compare the mean performances of the control group to the PDD-NOS group. Wilcoxon pairwise comparisons examined within-subjects effects. The statistical level of significance was set at $\alpha = .05$. In addition, after centering and scaling the data, a principal components analysis (PCA, Le Roux & Rouanet, 2004) examined the scatter of the six recognition scores (neutral visual, auditory, multimodal and emotional visual, auditory, and multimodal) across the control group (35 typically developing children), with the 10 PDD-NOS patients as supplementary elements. We express all values as mean $\pm$ standard error of the mean (SE).

## 3. Results

### 3.1. PDD-NOS versus control group in neutral and emotional stimuli processing

In the neutral task, a Mann–Whitney *U* test showed no significant differences between performance of the PDD-NOS and control groups (82.3 $\pm$ 5.5% vs. 91.6 $\pm$ 1.5%, respectively; $U = 124.0$, $Z = 1.39$, $p = .17$). This result confirms that the PDD-NOS group does not have an inability to perform this task. PDD-NOS and control groups also did not significantly differ on the visual task (82.6 $\pm$ 3.8% vs. 86.6 $\pm$ 1.8%, respectively; $U = 146.5$, $Z = 0.78$, $p = .44$) or in the auditory task (83.7 $\pm$ 4.9% vs. 93.5 $\pm$ 1.3%, respectively; $U = 110.5$, $Z = 1.76$, $p = .08$), but these groups did differ on the multimodal task (80.5 $\pm$ 7.7% vs. 94.7 $\pm$ 1.4%, respectively; $U = 102.5$, $Z = 1.98$, $p < .05$; see Fig. 2). The Wilcoxon signed-rank test determined whether participants performed some modalities were better within each group. For the PDD-NOS group, the differences between visual (82.6 $\pm$ 2.1%), auditory (83.7 $\pm$ 2.6%) and multimodal tasks (80.0 $\pm$ 4.1%) were not significant (all $Z < 1.00$, $p > .40$). The control group performed significantly better in the multimodal task (94.3 $\pm$ 1.5%) and the auditory task (93.5 $\pm$ 1.3%) but not in the visual task (86.6 $\pm$ 1.8%) compared to the children with PDD-NOS ($Z = 3.5$, $p < .001$ for multimodal vs. visual tasks; $Z = 3.0$, $p < .01$ for auditory vs. visual tasks).

Conversely, the PDD-NOS group performed significantly worse than the control group in the emotional tasks (70.6 $\pm$ 4.9% vs. 87.4 $\pm$ 1.0%, respectively; $U = 64$, $Z = 3.03$, $p < .01$; see Fig. 2). However, whereas children with PDD-NOS and control groups were significantly different on the visual task (53.3 $\pm$ 8.1% vs. 83.6 $\pm$ 2.2%, respectively; $U = 61.5$, $Z = 3.10$, $p < .001$) and on the auditory task (57.5 $\pm$ 7.3% vs. 81.4 $\pm$ 2.2%, respectively; $U = 69.0$, $Z = 2.89$, $p < .01$), there was no difference between the two groups on the multimodal task (66.7 $\pm$ 8.6% vs. 85.0 $\pm$ 2.3%, respectively; $U = 108.5$, $Z = 1.83$, $p = .06$). Additional Wilcoxon signed-rank tests did not reveal any differences between visual, auditory or multimodal conditions (all $p > .12$ in the PPD-NOS group and all $p > .16$ in the control group).

### 3.2. Identification of emotional expressions

We used three emotional expressions in this experiment: one positive (e.g., happy), two negative (e.g., angry and sad) as well as one neutral. Table 2 presents the mean correct response percentages for each group and each emotion. In the visual

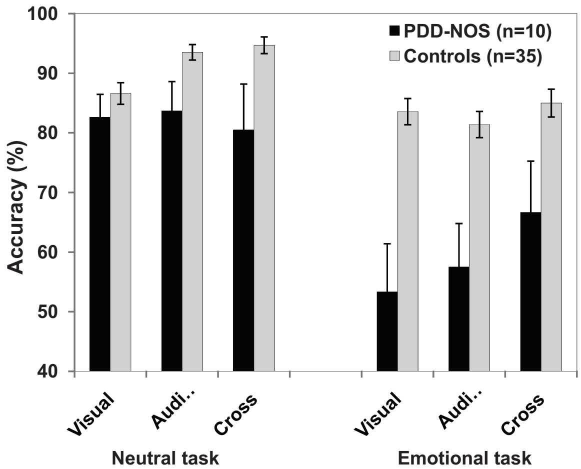


**Fig. 2.** Mean percentage of correct responses for neutral and emotional (visual, auditory and multimodal) tasks in PDD-NOS patients ($n = 10$) and typical control children ($n = 35$). Error bars represent the standard error of the mean (SE).

**Table 2**
Mean percentage of correct responses (±SE) for each emotion (e.g., happy, angry, sad, and neutral) in each task (e.g., visual, auditory, and multimodal) for both children with PDD-NOS and controls.

| | | Happy | Anger | Sad | Neutral |
|---|---|---|---|---|---|
| PDD-NOS (*n* = 10) | Visual | 70.0 (4.9) | 33.3 (6.5)* | 53.3 (6.1) | 56.7 (5.3)* |
| | Auditory | 83.3 (4.0) | 30.0 (3.6)* | 70.0 (4.9) | 46.7 (6.6)* |
| | Multimodal | 80.0 (5.4) | 63.3 (5.6) | 66.7 (6.5) | 56.7 (7.1)* |
| Control group (*n* = 35) | Visual | 85.7 (3.9) | 80.0 (4.5) | 84.8 (3.4) | 88.6 (3.5) |
| | Auditory | 94.3 (2.1) | 72.4 (4.1) | 77.1 (4.2) | 82.9 (4.3) |
| | Multimodal | 82.9 (3.9) | 82.9 (4.1) | 85.7 (3.6) | 88.6 (3.8) |

* Significant difference between PDD-NOS and control group ($p < .05$).

task, the PDD-NOS group identified significantly less angry ($U = 64.0$, $Z = 3.0$, $p < .01$), sad ($U = 83.0$, $Z = 2.5$, $p < .01$) and neutral faces ($U = 72.5$, $Z = 2.8$, $p < .01$) than the control group. There was no significant difference for happy faces ($U = 119.5$, $Z = 1.51$, $p = .12$). In the auditory task, the PDD-NOS group identified significantly less angry ($U = 57.0$, $Z = 3.2$, $p < .001$) and neutral stimuli ($U = 80.0$, $Z = 2.6$, $p < .01$) than the control group. There was no significant difference for happy ($U = 132.0$, $Z = 1.2$, $p = .24$) or sad stimuli ($U = 150.0$, $Z = .68$, $p = .49$). Finally, in the multimodal task, children with PDD-NOS did not differ from the control group (all $p > .09$), except for neutral multimodal stimuli ($U = 99.0$, $Z = 2.1$, $p < .05$).

### 3.3. *Profiles of children with PDD-NOS versus controls*

Four patterns emerged from the patient data, which we characterized as (a) global emotional and neutral processing deficits (patients 3, 6, 7, 8); (b) discrepancies between neutral and emotional facial identification skills compensated by multimodal processing (patients 2, 4, 5); (c) specific auditory emotional difficulties associated with a neutral multimodal weakness (patient 9); and (d) quasi-typical patterns in neutral and emotional processing (patient 1) with weaknesses in the visual emotional processing (patient 10).

Despite significant differences between children with PDD-NOS and the controls, there was a large individual variation among children with PDD-NOS. To understand the meaning of this individual variation, we performed an exploratory (given the sample size) principal component analysis (PCA). We retained the first two components (axes) whose contributions exceeded the mean contribution. These two components accounted for 51.6% of the total variance (Fig. 3A). Most of the initial variables were strongly correlated with the first three principal variables ($R^2 \geq .50$). In addition, the representation of individuals in the two-component space was relatively good (i.e., ≥.50 for 17 children). We interpret the two components as follows: the first included emotional and neutral multimodal processing as well as neutral auditory processing (29.8% of the variance) and may be regarded as a "cross-modal factor". The second component included auditory and visual emotional processing as well as neutral visual processing (21.8% of the variance) and may be regarded as an "emotional factor". Fig. 3B presents the individual performances of patients and controls based on these two components.

## 4. Discussion

We aimed to identify specific psychological patterns in children with PDD-NOS by comparing their human identification skills with normally developing children. We contrasted neutral versus emotional human stimuli, emotion type (e.g., happy, angry, sad, and neutral) and perceptual modalities (visual, verbal and multimodal). We used two experimental learning and judgment paradigms in congruent and incongruent conditions. We hypothesized that children with PDD-NOS would (a) accurately process neutral human stimuli; (b) have difficulty processing emotional information especially in the visual modality; and (c) compensate for the visual/auditory discrepancies using multimodal processing relative to the control group. Our results confirm most of these hypotheses and lead us to others.

The first finding in this study was the discrepancy between processing of neutral and emotional human stimuli. Children with PDD-NOS efficiently processed auditory, visual and multimodal neutral stimuli and performed significantly better on neutral compared to emotional tasks. In the complex learning neutral task, children with PDD-NOS effectively observed visual and auditory stimuli, recalled them (using visual and auditory short term memory), changed models (demonstrating cognitive flexibility), resisted distracters (showing an ability to ignore interference), chose target stimuli (by making judgments of similarity) and pressed the computer keys (demonstrating hand-eye coordination). Children with PDD-NOS correctly identified neutral human stimuli at least 80% of the time; however, they had difficulty processing emotional human stimuli in matching task that required much more cognitive resources. Children with PDD-NOS performed significantly worse than the control group in visual (54.6% vs. 83.7%) and auditory (56.4% vs. 81.7%) emotion judgment tasks but were comparable in the multimodal condition (70.3% vs. 85.1%). These results are similar to previous data that show that children with PDD-NOS have difficulties comprehending and interpreting social and emotional information (Gillberg, 1991; Serra et al., 2002; Volkmar et al., 2005). The emotional and cognitive deficits were associated with each other in some participants but not in other participants.

The second finding was the strong contrast between happy and angry faces. Children with PDD-NOS recognized happiness the easiest but found angriness the most difficult (70% vs. 33.3% in the visual condition; 83.3% vs. 30% in the

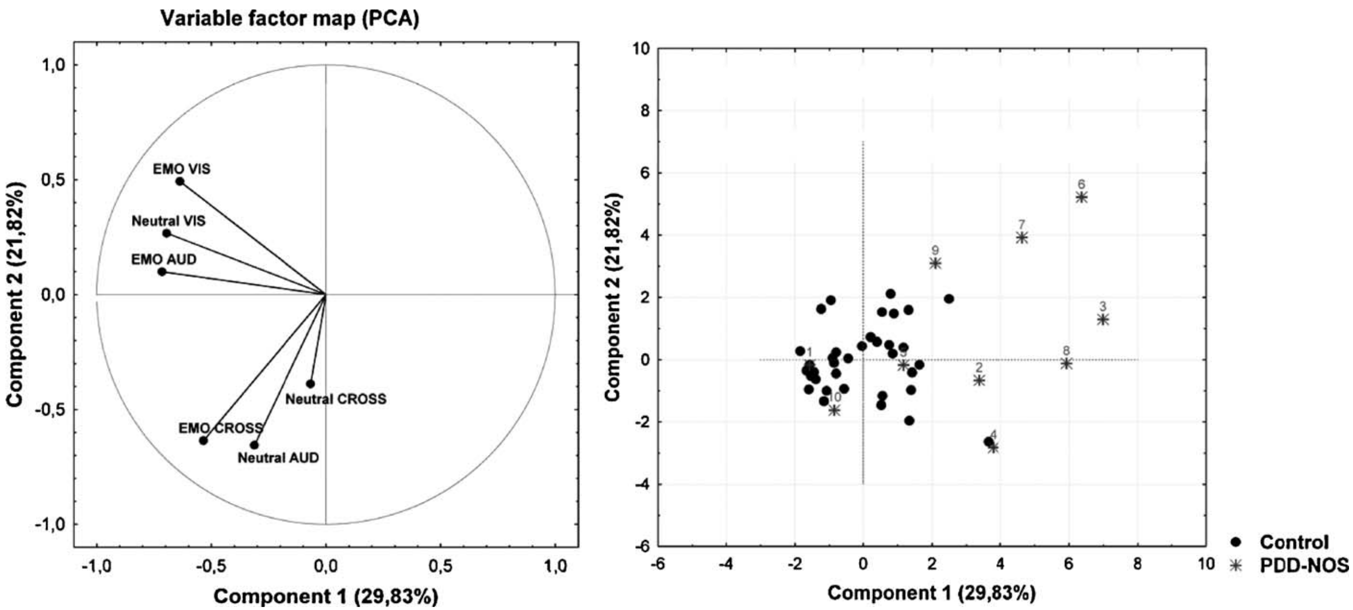


**Fig. 3.** Principal component analysis (PCA). (A) Space variable: "circle of correlations" (planes 1 and 2); (B) the cloud of participants in planes 1 and 2 for each of the six dependent variables (e.g., neutral visual, neutral auditory, neutral multimodal, emotional visual, emotional auditory, and emotional multimodal). Black circles represent normal children ($n = 35$) and gray cross represents children with PDD-NOS ($n = 10$).

auditory condition; 80% vs. 63.3% in the multimodal condition). Accurate happiness judgments corresponded to the pattern found in the control group, perhaps because happiness is the first positive emotion recognized during child development (Bornstein & Arterberry, 2003; Gosselin, 2005). Young infants reliably discriminate vocal, facial and multimodal expressions of happiness (Grossmann, 2010). The good performance on happy stimuli also shows that children with PDD-NOS understood task instructions, although this seems to be contradicted by their poor performance on angry judgments, which showed a floor effect and suggested responses at chance. Contrasts between performances on these two emotions are consistent with the current literature on threat avoidance bias in anxious children. Previous studies have documented information processing distortions in angry facial stimuli. These distortions include hostile attribution bias, which notably manifests as high rates of emotional misidentification, attention bias, and greater interference in concurrent psychological processes (Pine et al., 2005; Stirling et al., 2006). Our study suggests that the multimodal channel allowed the children to partially compensate for difficulties in identifying angry faces and voices.

The third finding was the observed weakness of neutrality recognition, which dramatically contrasts with the normal processing of neutral human stimuli in the learning paradigm task. This paradigm requires differentiating one human stimulus from another, whereas the emotion-based task requires identifying one neutral expression within two different human stimuli. This contrast might be explained by a tendency to project emotions on to neutral faces and voices more frequently than typically developing children.

The fourth finding was the observed difficulty in visual emotional (but not neutral) processing in children with PDD-NOS. This finding may fit with the observation that children with PDD-NOS and autism look at emotional faces less than normal children, especially the eyes and mouth, which support emotional communication (De Wit et al., 2008; Klin et al., 2002; Merin, Young, Ozonoff & Rogers, 2007; Pelphrey & Sasson, 2002). In our study, this difficulty did not alter the neutral face recognition and recall for children with PDD-NOS but did affect their emotion processing. Two hypotheses can explain the dissociation of neutral and emotional human stimuli. The first hypothesis is perceptual: neutral face identification requires individual differentiation of facial features and configuration, whereas emotion identification is based on action units (e.g., inner or outer brow raise, upper lid or lip raise, lip stretch, and so on), which participant must extract and combine to match faces. The second hypothesis concerns emotion experience, with which children with PDD-NOS might have confused cognitive representations because they may process emotions fundamentally different than normal children.

The fifth finding was that children with PDD-NOS showed specific strength in multimodal processing of emotional tasks, specifically with angry stimuli (33% in visual, 30% in auditory and 63% in cross-modal condition). This finding suggests that unimodal threat avoidance was partially compensated by a cross-modal channel. The children integrated information from visual and auditory modalities to form emotional representations that are unobtainable from these modalities in isolation. This hypothesis supports one principle of multimodal integration defined by Stein and Meredith (1993): multimodal integration is more efficient when the unimodal channels are weak, which allows for multiplicative effects. In contrast, children with PDD-NOS did not demonstrate a multimodal advantage in the neutral learning faces/names task, inasmuch as they were equally efficient in the visual and auditory processing. This may have practical implications for therapeutic approaches (Massaro & Bosseler, 2006; Williams et al., 2004). Future studies should use paradigms that avoid incongruent conditions, inasmuch as they increase attention allocation, and produce expectation violations (Grossmann, 2010).

The sixth finding was the strong heterogeneity of our sample of children with PDD-NOS with regard to their neutral, emotional and multimodal skills. This heterogeneity questions the internal validity of the PDD-NOS notion. We confirmed that there are different subtypes of PDD-NOS (e.g., de Bruin et al., 2007; Herba, de Bruin, Althaus, Verheij, & Ferdinand, 2008; Rondeau et al., in press; Zander & Dahlgren, 2010). Thus, practitioners should define a specific diagnosis using a dimensional rather than a categorical approach to individualize remediation programs.

## 5. Conclusion

Children with PDD-NOS present global emotional human stimuli processing difficulties, which dramatically contrast with their ability to process neutral human stimuli. Our study sample was strongly heterogeneous. These children had difficulties comprehending emotion and partially compensated for this problem using multimodal processing. Future studies with larger samples will allow researchers to confirm and refining these data, specifically by characterizing subgroups and delineating the cut-offs between PDD-NOS and other PDD types, especially autism.

## Acknowledgments

This research was supported by grants from the Fondation de France. We thank Jean Xavier and Sylvie Viaux for their help in diagnosis, Jean-Marc Guilé for his research direction advice, and Philippe Bonnet for his help with statistical analyses.

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