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ORIGINAL PAPER

Expressive Incoherence and Alexithymia in Autism Spectrum Disorder

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Abstract Expressive incoherence can be implicated in socio-emotional communicative problems in autism spectrum disorder (ASD). The present study examined expressive incoherence in 37 children with ASD and 41 typically developing (TD) children aged 3–13 years old during a frustration task. The role of alexithymia in expressive incoherence was also assessed. Compared to TD children, children with ASD had higher expressive incoherence, such as more neutral and positive emotion expressions during negative behaviors, but not in the expression of negative emotions during positive behaviors. Further analyses revealed that alexithymia moderated the expressions of positive emotions during negative behaviors. These results suggest that children with ASD may benefit from interventions targeting alexithymia to increase emotional coherence, which may improve socio-emotional communication.

Keywords Emotional response incoherence · Expressive incoherence · Alexithymia · Autism spectrum disorder

Children with autism spectrum disorder (ASD) are often reported to have difficulties with emotional functioning. Even though emotional impairments are not universal among individuals with ASD and are not unique to individuals with ASD, many children with ASD present emotional impairments in different domains (Nuske et al. 2013). Among these, children with ASD seem to have difficulties expressing their emotions adequately. At times, they are described as having flat emotional expressions despite having diversified emotional experiences (Weiss et al. 2013) or their emotional facial expression does not match the situational context (e.g. Kasari et al. 1990). Furthermore, emotional response incoherence has been linked to emotional and cognitive problems in clinical (Weinberg and Tronick 1994) and non-clinical populations (Niedenthal 2007). Moreover, alexithymia, i.e. the inability to recognize, describe, and distinguish emotions (Sifneos 1973; Taylor et al. 1997), may be an important factor in the explanation of emotional response incoherence in ASD. Alexithymia is highly prevalent in ASD and is known to be related to some (but not all) emotional difficulties in individuals with ASD (e.g. Cook et al. 2013; Samson et al. 2012). Understanding the nature of emotional response incoherence in children with ASD as well as the role of alexithymia is fundamental for the development of interventions that aim at improving communication and socio-emotional skills.

Emotional Response Coherence

Pleasant events are usually accompanied by a combination of emotional responses from different systems. For instance, the emotional changes associated to receiving a gift can be manifested by changes in subjective experience (e.g. feeling good), expression (e.g. looking happy), and physiology (e.g. increase in heart rate). The coherence among these different emotional response systems is one of

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the central features that define emotion (e.g. Ekman 1992; Lazarus 1991; Levenson 1994; Tomkins 1962). Emotional response coherence refers to the coordinated changes across emotional response systems and is present since birth (Malatesta et al. 1989). It has important implications for how an individual must respond to environmental demands (e.g. Levenson 1994) as well as for social functioning by facilitating the communication of subjective experiences to others.

The construct of emotional response coherence is often associated with an evolutionary perspective on the function of emotions (Evers et al. 2014). Coherence is thought to represent an adaptive system that creates optimal conditions for the organism to deal with different demands (e.g. Ekman 1992; Levenson 1994; Tomkins 1962). The internally-driven perspective of this theory posits that coherence is due to a central organization of emotion in the brain (e.g. Rosenberg and Ekman 1994), while the externally-driven perspective posits that coherence is due to facial-feedback (e.g. Ekman 1993; Laird 1974), where facial expressions influence the other systems (e.g. making a facial expression leads to the subjective experience of that emotion including associated physiological changes).

Although there exists strong theoretical support for the construct of emotional response coherence, empirical results have been inconclusive (Barrett 2006; Sze et al. 2010). While some studies found support for coherence (e.g. Mauss et al. 2005; Rosenberg and Ekman 1994), others found none (e.g. Fernandez-Dols et al. 1997; Kraut and Johnston 1979), and some even found support for a negative relation among systems (e.g. Buck 1980; Lanzetta and Kleck 1970). However, growing evidence indicates that different results may depend to some extent on paradigms and different approaches to examine emotional response coherence. Results of studies using a between-individual paradigm are usually less supportive of coherence than studies using a within-individual paradigm (Cacioppo et al. 1992; Rosenberg and Ekman 1994; Sze et al. 2010). Studies that apply a between-individual paradigm analyze the extent to which individuals presenting more of system's response also present more of another system's response. Studies that apply a within-individual paradigm analyze which system's responses coordinate.

Another paradigm distinction lies on which responses are being included. The dual-process frameworks (Evers et al. 2014) posit that coherence occurs differently across automatic and reflective responses. Responses that are both automatic (e.g. heart-rate and skin conductance), or both reflective (e.g. self-report and behavior) tend to coordinate with each other, while automatic and reflective responses tend to not coordinate. According to the dual-process frameworks (Evers et al. 2014), expressive coherence is a type of emotional response coherence in which responses are part of the same system and should therefore coordinate. This idea is also consistent with the conceptualization of emotions as tripartite complexes (Izard 1977; Malatesta 1981), which postulates that emotions are conveyed by facial expressions, vocalizations, and body postures (Weinberg and Tronick 1994).

Finally, emotional response coherence can be difficult to examine due to its temporal differences (Mauss et al. 2005). Emotional response systems differ in the timecourse of how emotions evolve and are expressed as well as in how transient they are.

Emotional Response Incoherence

Emotional response incoherence may occur when different emotion response systems contradict each other such as when the expression does not match the subjective experience (e.g. smiling while feeling sad), when the expression does not match the physiological response (e.g. no visible facial expression while having a significant increase in heart-rate), or when the subjective experience does not match the physiological response (e.g. reporting no change in emotion while an increase in heart-rate is observed). Emotional response incoherence may also occur when different responses from the same system do not match (e.g. expressing positive emotions while engaging in aggressive behavior).

Emotional response incoherence might be important for the adjustment of some social interactions where the expression of an emotion is not appropriate. In the example of receiving a gift, emotional response incoherence could occur if the gift would be unpleasant but the individual would not want to show disappointment. However, even this type of normative emotional response incoherence comes at certain costs (Niedenthal 2007). Suppressing the expression of emotions has been associated with detrimental long-term effects for mental health and well-being (John and Gross 2004). Furthermore, incoherence decreases speed of answer (Duckworth et al. 2002), positive mood (Stepper and Strack 1993), memory (Alter and Oppenheimer 2009), cognitive performance (Centerbar et al. 2008), and increases stress levels (Grandey 2003).

Incoherence has also been reported to characterize children with cognitive, affective, and neurological disorders and may serve as an indicator for the identification of emotional and behavior difficulties in these children (Weinberg and Tronick 1994).

Emotional Response Incoherence in ASD

Several accounts have suggested that children with ASD present a type of incoherence that is different from the normative emotional response incoherence used for social purposes, such as when a child smiles when receiving a disappointing gift. Since the first accounts of the characteristics presented by children with ASD (Asperger 1944; Kanner 1968), uncommon emotional facial expression's production has been described (Brewer et al. 2016; Faso et al. 2015; Volker et al. 2009).

In one study where spontaneous emotional expressions were coded during a child-experimenter interaction (Yirmiya et al. 1989), it was found that children with ASD displayed ambiguous facial expressions that were not displayed by any of the typically developing (TD) children. Using a paradigm in which children were requested to retell an emotionally charged story, it was shown that facial expressions of children with ASD were less natural and more awkward than those of TD children (Grossman et al. 2013). It has also been found that children with ASD express as many spontaneous emotions as TD children and children with intellectual disability but that their emotional expression occurs less often in a meaningful communicative setting (Bieberich and Morgan 2004; Dawson et al. 1990; Kasari et al. 1990) or in less coherent contextual events (McGee et al. 1991).

In a study assessing emotional responses to odors (Legiša et al. 2013), children with ASD had similar expressive and physiological responses to the odors as TD children but the facial expressions of children with ASD were less likely to match their subjective experience. Moreover, children with ASD showed incoherence between subjective feelings of amusement and smiling and laughing behavior in a simple but effective humor task (Weiss et al. 2013).

However, another study showed that children with ASD seem to laugh only to express positive emotions and not for social communicative reasons (Hudenko and Magenheimer 2012). This behavior might be seen as situationally incoherent but coherent in terms of the coordination between the emotional response systems (i.e. subjective experience and expression).

Emotional Response Incoherence in ASD and the Role of Alexithymia

Ekman (1993) has proposed that the occurrence of emotional response incoherence could be due to the individual's difficulty to properly report own emotions. If an individual has difficulties understanding and reporting own emotions, such as when an individual has high levels of alexithymia, then the individual would have more difficulties matching their emotional expression to their subjective experience.

Alexithymia is a transdiagnostic deficit that encompasses difficulties identifying and describing emotions (Nemiah et al. 1976; Sifneos 1973). Alexithymia impairs both the experience and the expression of emotion (Taylor et al. 1997). It has an impact at both intrapersonal and interpersonal levels and has been linked to socio-affective deficits such as a lack of empathy (Guttman and Laporte 2002). The few studies that have examined alexithymia in children with ASD have found that, similarly to adults (Berthoz and Hill 2005), alexithymia is more prevalent among children with ASD than among TD children (Griffin et al. 2015; Rieffe et al. 2007). In one study it was found that the facial expressions of individuals with higher levels of alexithymia appeared to be odder than of those with lower levels (Brewer et al. 2016). Which led the authors to suggest that despite the overlap between alexithymia and ASD, alexithymia may be linked to atypical emotional expressions in ASD (Brewer et al. 2016). Therefore, alexithymia could play an important role in the explanation of emotional response incoherence in individuals with ASD.

Furthermore, alexithymia has been linked to difficulties with the recognition of emotional facial expression in both TD individuals (Lane et al. 1996; Parker et al. 1993; Prkachin et al. 2009) and individuals with ASD (Cook et al. 2013; Kätsyri et al. 2008). Interestingly, in individuals with ASD it has been shown that the impairments with the recognition of emotional facial expression may be attributed to comorbid alexithymia rather than to the clinical condition of the individual (Grynberg et al. 2012). Alexithymia has also been shown to play an important role in other (but not all) emotional difficulties in individuals with ASD such as empathy (Bird et al. 2010) and eye-fixation (Bird et al. 2011).

Alexithymia's core characteristics (difficulties identifying and describing emotions), which are fundamental for a child's ability to understand inner states and match emotional responses to them, could therefore offer new perspectives in understanding the underlying mechanisms and related factors leading to emotional response incoherence in children with ASD.

The Present Study

The study of expressive coherence in children with ASD seems a relevant one. In case of incoherence, a child might be communicating mixed information, which can contribute to the social and communication problems identified in these children. An adult who observes a child expressing positive emotions (e.g. smiling) while engaging in negative behavior (e.g. punching a table) might get confused as to whether the

Table 1 Possible dyads between co-occurring behaviors and facial expressions with examples and resulting coherence status (coherent or incoherent)

Behavior	Facial expression	Example	Coherence
Negative	Negative	Stomping feet with an angry facial expression	Coherent
	Neutral	Complaining with a neutral facial expression	**Incoherent**
	Positive	Hitting the table with a happy facial expression	**Incoherent**
Neutral	Negative	Looking at the toy with a sad facial expression	Coherent
	Neutral	Playing with fingers with a neutral facial expression	Coherent
	Positive	Staring into space with a positive facial expression	Coherent
Positive	Negative	Helping return the toy with an angry facial expression	**Incoherent**
	Neutral	Asking to play longer with a neutral facial expression	Coherent
	Positive	Engaging in imaginary play with happy facial expression	Coherent

Incoherent dyads are highlighted in bold

child is really upset or not. This can have consequences on the way the adult will interact with the child and the support given. To our knowledge, no study has so far assessed expressive incoherence in children with ASD. However, this area might contribute to a better understanding of the socio-emotional difficulties encountered by these children.

The first aim of the present study was to analyze if children with ASD, compared to TD children, show more expressive incoherence during a frustration eliciting situation. Expressive incoherence was conceptualized as a mismatch between the behavior (i.e. negative, neutral, and positive behaviors) and the simultaneous facial expression (i.e. negative, neutral, and positive facial expressions; see Table 1). This conceptualization resulted in nine dyads of which three were considered incoherent: negative behaviors co-occurring with neutral facial expressions, negative behaviors co-occurring with positive facial expressions, and positive behaviors co-occurring with negative facial expressions. All other dyads were considered coherent. Expressive incoherence was chosen for four methodological reasons: (a) facial expression and behavior are both responses from the expressive system and therefore, according to the dual-process frameworks (Evers et al. 2014), coherence is expected to occur; (b) expressive coherence allows for a comparison at a within-individual level and results using this paradigm have been supportive of the existence of coherence (Rosenberg and Ekman 1994); (c) incoherence can be assessed through observation, avoiding therefore problems related to children's difficulties reporting own emotions (Ekman 1993); and (d) the influence of temporal differences across emotional response systems is avoided (Mauss et al. 2005).

The second aim of this study was to analyze the role that alexithymia plays in expressive incoherence. Because of alexithymia's high prevalence among individuals with ASD and its known role in emotional difficulties among individuals with ASD, it is possible that alexithymia might also play a role in expressive incoherence. If children with ASD have more alexithymia and therefore have more difficulties understanding their own emotions, this could generate difficulties accurately matching the different expressive responses. Therefore, alexithymia could possibly explain expressive incoherence beyond diagnostic status (ASD/TD).

To our knowledge it is the first time that different types of expressive incoherence have been analyzed in children with ASD. However, based on the existing literature on emotional incoherence in ASD, it was expected that children with ASD present more expressive incoherence than TD children in all three expressive incoherence subtypes and that alexithymia plays a role in the explanation of expressive incoherence.

The hypotheses for our research questions were that (a) children with ASD show more expressive incoherence than TD children in all expressive incoherence subtypes (more negative behaviors co-occurring with neutral facial expressions, more negative behaviors co-occurring with positive facial expressions, and more positive behaviors co-occurring with negative facial expressions), that (b) taking alexithymia into account, group differences in expressive incoherence disappear, and that (c) alexithymia moderates the incoherence between facial expression and behavior.

Methods

Participants

Thirty-seven children previously diagnosed with ASD[1] (5 female) and 41 TD children (9 female) aged 3 to 13 years

[1] Among the 37 children diagnosed with ASD 20 had been previously diagnosed with low-functioning ASD (3 female) and 17 had been previously diagnosed with high-functioning ASD (2 female). Children in the low-functioning ASD group had either intellectual or language delays, or both, and attended special education schools. Children in the high-functioning group did not have any intellectual or language delays and attended regular schools. Analyses comparing children with low-functioning ASD and high-functioning ASD were carried out (see Online Resources 1 through 3) and confirmed that children who were previously diagnosed with low-functioning ASD did not differ from children who were previously diagnosed with high-functioning ASD in a way that would affect the interpretation of the results.

Table 2 Sample characteristics: Means (*M*), standard deviations (*SD*), ranges, sample size, Pearson's chi square values, *t* values, and significance levels (*p*) for age and gender differences between children with ASD and TD children and their parents

	ASD *M* (*SD*, range) *n* = 37	TD *M* (*SD*, range) *n* = 41	Statistics (ASD/TD)
Children			
Male/Female	32/5	32/9	$\chi 2(1) = 0.94$, $p = .33$
Age	9.07 (2.60, 3–13)	8.42 (2.20, 4–13)	$t(76) = 1.20$, $p = .23$
Parents			
Mother[a]/Father	31/6	36/5	$\chi^2(1) = 0.26$, $p = .61$
Age	41.29 (4.88, 33–53)	39.12 (4.77, 26–49)	$t(74) = 1.95$, $p = .06$

ASD autism spectrum disorder, *TD* typically developing

[a]Two of the mothers of children with ASD were grand-mothers who were the legal representatives of the child since the child was an infant

old, together with one of their caregivers, participated in the study (see Table 2).

Children with ASD had previously been diagnosed by a pediatrician or by a multi-disciplinary team of professionals working with children with ASD and had a governmentally recognized diagnosis of ASD, which is also the basis for obtaining health insurance provisions. Participants in this study were part of a larger study on emotional reactivity and emotion regulation.

Procedure

General Procedure

Invitations to participate in the study were sent to parents of children with ASD through institutions for children with ASD and to parents of TD children through regular primary schools. Parents and, when possible, children read and signed informed consent forms for participation and data collection. The study consisted of a single visit where children were requested to come with one of their parents. During the visit, parents were requested to fill out a demographics' questionnaire and a questionnaire about their children's alexithymia. No self-report questionnaires were used due to the level of functioning and age of some of the children who participated in the study. Questionnaires were filled out by parents in French ($n = 55$), German ($n = 16$), or English ($n = 7$) according to parents' language preference. No effects of language were found to significantly affect the results on any of the outcome variables (see Online Resource 4). After the questionnaires were completed, children were observed during a frustration eliciting situation in a laboratory setting. The study was carried out by the first author together with three student assistants in order to help with the different languages. Prior to contact with parents and children, the study was reviewed and approved by the university's ethics review panel.

Frustration Eliciting Situation: Attractive Toy Removal

In this procedure adapted from the Laboratory Temperament Assessment Battery (Goldsmith and Rothbart 1999), the child sat at a table and one of the parents sat at the child's left side. The child was given the choice to play with attractive age-appropriate toys. Approximately 15 s after the child began playing, the researcher removed the toys in an abrupt manner and placed them behind a transparent barrier in front of the child for 30 s. The barrier was placed at the child's reach and the toys could be seen through the transparent barrier. After the 30 s, the researcher returned the toys to the child and the same procedure was repeated two more times. Children were frontally videotaped during the whole situation. The three moments without the toy (frustration moments) were coded by two independent observers, in which one of the observers was aware of the study conditions while the other was unaware of both the aims of the study and the sample characteristics. The coding was made in 10-s intervals resulting in nine coded episodes per child. No effects of parental interaction were found to significantly affect the results on any of the outcome variables (see Online Resource 4).

Measures

Measure of Facial Expression Valence

Children's facial expressions during the frustration moments of the Attractive Toy Removal situation were coded in terms of the following five categories: sad, angry, afraid, neutral, and happy. Inter-rater reliability between the two coders for 100% of the data yielded a good level of Cohen's Kappa measure of agreement, $\kappa = 0.76$ (95%CI 0.71 to 0.80), $p < .001$. Emotional expressions were coded using the emotional facial action coding system (EMFACS) guidelines (Ekman and Friesen 1978; Friesen and Ekman 1983) using a combination of different action units for each emotion (see Online Resource 5). Emotional facial

Table 3 Behaviors' valences (adapted from Feng et al. 2008) grouping regulatory behaviors used by children during a frustration situation and their description organized from least to most adaptive (adapted from Grolnick et al. 1996; Konstantareas and Stewart 2006)

Behaviors' valences (adapted from Feng et al. 2008)	Regulatory behaviors (Grolnick et al. 1996; Konstantareas and Stewart 2006)	Description of typical behavior
Negative behavior	Physical objection	Hitting (hands, feet, head)
	Crying/venting	Crying/whimper/stomping feet/little cries/stimming
	Defending	Hiding the toy / trying to hold the toy back
	Infraction	Retrieving or trying to retrieve the toy from behind barrier
	Verbal objection	Saying "No"/complaining
Neutral behavior	Staring	Staring at the toy behind the barrier
	Doing nothing	Staring into space
	Self-distraction	Playing with clothing/fingers
	Parent / researcher	Talking or making sounds (for non-verbal children) towards the parent or researcher (not oriented at the toy)
Positive behavior	Directing situation	Asking for playing longer or to have the toy/pointing at the toy (for non-verbal children)
	Engaging in alternative activity	Leaving to play with other toys/engaging in imaginary play
	Complying	Returning the toy immediately/helping return the toy

expressions were analyzed in terms of valence: negative (sad, angry, and afraid), neutral, and positive (happy) facial expressions.

Measure of Behavior Valences

Children's regulatory behaviors during the frustration moments of the attractive toy removal situation were coded according to children's common reactions to a mildly frustrating situation (Table 3). These behaviors are based on the work of Grolnick et al. (1996) and adapted by Konstantareas and Stewart (2006). The rating categories are ordered from least adaptive to most adaptive: physical objection, crying / venting, defending, infraction, verbal objection, staring, doing nothing, self-distraction, parent / researcher, directing situation, engaging in alternative activity, and complying. Behaviors were coded by two independent coders in 10-second intervals. The intervals corresponded temporarily to the intervals coded for emotional facial expression. Inter-rater reliability between the two coders for 100% of the data yielded a very good level of Cohen's Kappa measure of agreement, $\kappa = 0.84$ (95%CI 0.81 to 0.87), $p < .001$. The 12 regulatory behaviors were grouped into three categories of behavior valences (categories adapted from Feng et al. 2008): negative, neutral, and positive behaviors (see Table 3).

Measure of Expressive Incoherence

Expressive incoherence was analyzed by comparing the behaviors and the facial expressions occurring simultaneously during the frustration eliciting situation. Because we analyzed three behavior valences (negative, neutral, and positive) and three facial expression valences (negative, neutral, and positive), nine dyads were possible. Based on the nature of the task being performed and the conceptualization of incoherence as a mismatch between behavior and simultaneous facial expression, three of these nine dyads were considered incoherent (see Table 1 for examples): the occurrence of negative behaviors was incoherent with neutral facial expressions (Negative Beh./Neutral Expr.), the occurrence of negative behaviors was incoherent with positive facial expressions (Negative Beh./Positive Expr.), and the occurrence of positive behaviors was incoherent with negative facial expressions (Positive Beh./Negative Expr.). The remaining six dyads were considered coherent (see Table 1 for examples): dyads of the same valence were naturally considered coherent, dyads in which a neutral behavior occurred were all considered coherent because any facial expression can coherently occur with a neutral behavior, finally a positive behavior co-occurring with a neutral facial expression was also considered coherent due to the nature of the task. The ratio between the amount of incoherent intervals over the total amount of intervals was calculated and expressed in percentages.

Measure of Alexithymia

The Alexithymia Questionnaire for Children-Parent report (AQC-P) is a 20-item parent-report questionnaire that measures children's alexithymia. The questionnaire is an adaptation of the Alexithymia Questionnaire for Children (Rieffe et al. 2006) in which the items were reformulated to be parent-report items (e.g. "My child finds it difficult

to say how he/she feels inside"). Parents were asked to rate the degree to which they agreed to statements concerning their child on a 3-point scale ranging from "not true" to "often true" with an additional option for "does not apply". The items represent three aspects of alexithymia: seven items assessing difficulty identifying feelings (e.g. "When my child is upset, he / she does not know if he / she is sad, scared, or angry"), five items assessing difficulty describing feelings (e.g. "My child can easily say how he / she feels inside"), and eight items assessing externally-oriented thinking (e.g. "My child considers important to understand how he / she feels inside"). The items were translated and back-translated into French and German by two independent native speakers who were also fluent in English. Inconsistencies in translation (e.g. choice of different words, sentence formulation) were discussed by the translators and resolved with the help of the main researcher. The 20 items were added to obtain a total alexithymia score. Internal consistencies, computed on the basis of the sample described here, proved satisfactory. Cronbach's alpha was 0.73 for the French version and 0.86 for the German version.

Statistical Analyses

First, children with ASD were compared to TD children in behavior valences, facial expression valences, and alexithymia using MANOVA Wilks's lambda tests followed by post-hoc ANOVAs. Because age (Izard and Malatesta 1987) and gender (Chaplin 2015) can influence emotional expression and age can influence the relation between alexithymia and emotional disturbances (Sendzik et al. 2017), MANCOVAs followed by ANCOVAs with age and gender entered as covariates were conducted to control for effects of these control variables on behavior valences, facial expression valences, and alexithymia between children with ASD and TD children.

MANOVA Wilks's lambda tests were used to compare children with ASD and TD children in expressive incoherence and post-hoc ANOVAs were used to determine groups' differences across the three types of expressive incoherence. A MANCOVA followed by ANCOVAs with alexithymia as covariate were used to examine the stability of group differences in the different types of expressive incoherence. Bonferroni corrections were applied to all univariate tests.

Because alexithymia had an effect on the expression of positive emotions during negative behaviors, a hierarchical regression analysis was conducted to further examine the role of alexithymia in expressive incoherence. Positive emotions were regressed by entering demographic variables (age and gender) in the first step, *z*-standardized alexithymia and negative behavior were entered in the second step, and the cross product of alexithymia and negative behavior was entered in the third step.

Results

Group Differences in Behavior Valences, Facial Expression Valences, and Alexithymia

MANOVA Wilks's lambda tests were used to compare children with ASD and TD children in behavior valences, facial expression valences, and alexithymia (Table 4). Regarding behavior valences a significant effect of group was found [$\Lambda = 0.71$, $F(3,74) = 10.26$, $p < .001$, $\eta_p^2 = 0.29$]. Separate univariate ANOVAs revealed that children with ASD used more negative [$F(1,76) = 25.24$, $p < 0.001$, $\eta_p^2 = 0.25$] and less neutral behaviors [$F(1,76) = 11.35$, $p < 0.01$, $\eta_p^2 = 0.13$] than TD children but did not differ on the use of positive behaviors [$F(1,76) = 2.03$, $p = 0.16$, $\eta_p^2 = 0.03$].

Regarding facial expression valences, a significant effect of group was found [$\Lambda = 0.69$, $F(3,74) = 11.33$, $p < .001$, $\eta_p^2 = 0.32$]. Separate univariate ANOVAs revealed significant group effects on all facial expression valences. Children with ASD displayed more negative [$F(1,76) = 7.74$, $p < 0.01$, $\eta_p^2 = 0.09$], more neutral [$F(1,76) = 7.85$, $p < 0.01$, $\eta_p^2 = 0.09$], and less positive [$F(1,76) = 25.17$, $p < .001$, $\eta_p^2 = 0.25$] facial expressions than TD children.

Regarding alexithymia, a significant effect of group was found [$\Lambda = 0.66$, $F(3,74) = 12.78$, $p < .001$, $\eta_p^2 = 0.34$]. Separate univariate ANOVAs revealed that children with ASD were reported by their parents has having more difficulties identifying feelings [$F(1,76) = 38.34$, $p < 0.001$, $\eta_p^2 = 0.34$] and more difficulties describing feelings [$F(1,76) = 15.17$, $p < 0.001$, $\eta_p^2 = 0.17$] than TD children. However, no significant differences were found among groups regarding externally oriented thinking [$F(1,76) = 2.40$, $p = 0.13$, $\eta_p^2 = 0.03$].

Age and Gender Effects in Behavior Valences, Facial Expression Valences, and Alexithymia Between Children with ASD and TD Children

MANCOVAs controlling for age and gender effects were employed on behavior valences, facial expression valences, and alexithymia. Age and gender did not affect group differences on any of the outcome variables (see Online Resource 4).

Group Differences in Expressive Incoherence

Using MANOVA Wilks's lambda tests, a significant effect of group on children's expressive incoherence [$\Lambda = 0.86$, $F(3,74) = 3.88$, $p < .05$, $\eta_p^2 = 0.14$] was found (Table 5). Separate univariate ANOVAs across the three sub-types of

Table 4 Means (*M*), standard deviations (*SD*), *F* values (MANOVA and ANOVA), significance levels, and effect sizes (η_p^2) of behavior valences, facial expression valences, and alexithymia (AQC-P)

	ASD *M* (*SD*)	TD *M* (*SD*)	Statistics (ASD/TD)	
Behavior valences			$F(3,74) = 10.26^{***}$	$\eta_p^2 = 0.29$
Negative	2.59 (2.89)	0.27 (0.63)	$F(1,76) = 25.24^{***}$	$\eta_p^2 = 0.25$
Neutral	5.05 (3.01)	6.98 (1.97)	$F(1,76) = 11.35^{**}$	$\eta_p^2 = 0.13$
Positive	1.16 (1.89)	1.76 (1.79)	$F(1,76) = 2.03$	$\eta_p^2 = 0.03$
Facial expression valences			$F(3,74) = 11.33^{***}$	$\eta_p^2 = 0.32$
Negative	1.46 (2.09)	0.46 (0.90)	$F(1,76) = 7.74^{**}$	$\eta_p^2 = 0.09$
Neutral	5.78 (2.90)	3.85 (3.16)	$F(1,76) = 7.85^{**}$	$\eta_p^2 = 0.09$
Positive	1.49 (1.97)	4.68 (3.39)	$F(1,76) = 25.17^{***}$	$\eta_p^2 = 0.25$
Alexithymia (AQC-P)	21.51 (7.06)	13.76 (6.70)	$F(3,74) = 12.78^{***}$	$\eta_p^2 = 0.34$
Difficulty identifying feelings	8.19 (3.19)	3.93 (2.89)	$F(1,76) = 38.34^{***}$	$\eta_p^2 = 0.34$
Difficulty describing feelings	6.19 (2.75)	3.80 (2.65)	$F(1,76) = 15.17^{***}$	$\eta_p^2 = 0.17$
Externally oriented thinking	7.14 (3.22)	6.02 (3.12)	$F(1,76) = 2.40$	$\eta_p^2 = 0.03$

ASD autism spectrum disorder, *TD* typically developing, *AQC-P* Alexithymia Questionnaire for Children-Parent version (total score)

$^{**}p < .01$, $^{***}p < .001$

Table 5 Means (*M*), standard deviations (*SD*), *F*-values (MANOVA and ANOVA), significance levels, and effect sizes (η_p^2) of percentage of expressive incoherence for children with ASD and TD children; *F*-values (MANCOVA and ANCOVAs), significance levels, and effect sizes (η_p^2) for percentage of expressive incoherence for children with ASD and TD children after controlling for alexithymia (AQC-P)

Facial expression valence / Behavior valence	ASD *M* (*SD*)	TD *M* (*SD*)	Statistics (ASD / TD)		Statistics (ASD / TD) (controlling for alexithymia)	
Expressive incoherence (%)						
Total	18.81 (25.96)	2.98 (6.10)	$F(3,74) = 3.88^{*}$	$\eta_p^2 = 0.14$	$F(3,73) = 3.99^{*}$	$\eta_p^2 = 0.14$
Negative Beh./Neutral Expr	13.66 (27.48)	0.35 (2.23)	$F(1,76) = 9.57^{**}$	$\eta_p^2 = 0.11$	$F(1,75) = 11.43^{**}$	$\eta_p^2 = 0.13$
Negative Beh./Positive Expr	20.59 (34.83)	5.70 (19.50)	$F(1,76) = 5.56^{*}$	$\eta_p^2 = 0.07$	$F(1,75) = 3.39$	$\eta_p^2 = 0.04$
Positive Beh./Negative Expr	4.32 (18.94)	5.69 (22.24)	$F(1,76) = 0.08$	$\eta_p^2 = 0.00$	$F(1,75) = 0.00$	$\eta_p^2 = 0.00$

ASD autism spectrum disorder, *TD* typically developing, *AQC-P* Alexithymia Questionnaire for Children – Parent version (total score), *Expr*. Facial expression valence, *Beh*. Behavior valence

$^{*}p < .05$, $^{**}p < .01$

expressive incoherence revealed that children with ASD, compared to TD children, had a higher percentage of Negative Beh./Neutral Expr. [$F(1,76)=9.57$, $p<0.01$, $\eta_p^2 = 0.11$] and Negative Beh./Positive Expr. [$F(1,76) = 5.56$, $p < 0.05$, $\eta_p^2 = 0.07$] but did not differ in the percentage of Positive Beh./Negative Expr. [$F(1,76) = 0.08$, $p = 0.77$, $\eta_p^2 = 0.00$].

Effects of Alexithymia on Expressive Incoherence

MANCOVAs including alexithymia as covariate, revealed that alexithymia did not affect differences between children with ASD and TD children in the overall percentage of expressive incoherence [$F(3,73) = 3.99$, $p < .05$, $\eta_p^2 = 0.14$] (Table 5). Further ANCOVAs revealed that alexithymia did not affect the percentage of Negative Beh./Neutral Expr. [$F(1,75) = 11.43$, $p < 0.01$, $\eta_p^2 = 0.13$] and Positive Beh./Negative Expr. [$F(1,75) = 0.00$, $p = 0.95$, $\eta_p^2 = 0.00$] incoherence. However, alexithymia affected the percentage of Negative Beh./Positive Expr. incoherence in a way that taking alexithymia into account, children with ASD no longer differed from TD children [$F(1,75) = 3.39$, $p = 0.07$, $\eta_p^2 = 0.04$].

To further test the effect of alexithymia on the percentage of Negative Beh./Positive Expr. incoherence a hierarchical multiple regression analysis was conducted where

Table 6 Three-step hierarchical multiple regression analysis for variables predicting positive emotional expression

Variables	β	SE β
Step 1		
Age	0.03	0.15
Gender	2.01*	0.96
Step 2		
Age	0.05	0.16
Gender	1.94*	0.96
Alexithymia (AQC-P)	−0.39	0.37
Negative Beh	−0.33	0.36
Step 3		
Age	0.00	0.15
Gender	2.10*	0.92
AQC-P	−0.31	0.36
Negative Beh	−0.51	0.35
AQC-P × Negative Beh	0.99**	0.35

AQC-P Alexithymia Questionnaire for Children-Parent version (total score), *Beh*. Behavior

Control variables: age and gender. Predictors: *z*-standardized alexithymia (AQC-P), *z*-standardized negative behavior, and the cross product of both

$R^2 = 0.06$ for Step 1 ($p = .11$); $\Delta R^2 = 0.03$ for step 2 ($p = .34$); $\Delta R^2 = 0.09$ for step 3 ($p < .01$)

*$p < .05$, **$p < .01$

alexithymia effects were tested on the relation between negative behavior and positive facial expression. Because there were no language of assessment and parental interaction effects on behavior valences and facial expression results and because including these variables the resulting pattern remained the same, we excluded these control variables from the reported regression for reasons of parsimony and sample power. Including age and gender as control variables and regressing positive facial expression on *z*-standardized alexithymia (AQC-P), negative behavior, and the cross product of both incrementally accounted for a significant amount of variance of the dependent variable (Table 6).

On multivariate level none of the predictors was associated with positive facial expression. However, an interaction effect was found, as the cross product of alexithymia and negative behavior incrementally predicted positive facial expression above and beyond the other effects. Children with low levels of alexithymia (−1 *SD*) displayed more positive emotions at low levels of negative behavior (−1 *SD*) than at high levels of negative behavior (+1 *SD*), while children with high levels of alexithymia (+1 *SD*) displayed similar amounts of positive emotions at low and high levels of negative behavior (±1 *SD*; Fig. 1).

Simple slope analyses confirmed this interpretation: a significant negative effect was found between negative behavior and positive emotions at low levels of alexithymia [$b = -1.44$, $SE = 0.55$, $p < .01$], but negative behavior was not related to positive emotions at high levels of alexithymia [$b = 0.39$, $SE = 0.46$, $p = .40$].

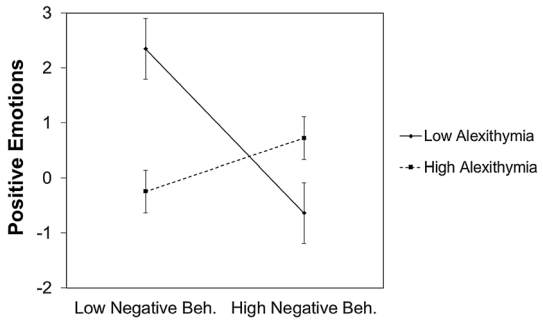

Fig. 1 Regressing expression of positive emotions as function of alexithymia (±1 *SD*) and negative behavior (±1 *SD*) with standard errors' bars

Gender was found to be significantly associated with positive facial expression even after entering the predictors. In order to control for possible effects of gender, a hierarchical multiple regression analysis was conducted (see Online Resource 6). The analyses revealed that on a 2-way level, no interaction effects of gender with the predictors could be found. Furthermore, no 3-way interaction could be established.

Discussion

With the present study we examined whether, similarly to other types of emotional response incoherence reported in the literature (e.g. Grossman et al. 2013), children with ASD present more expressive incoherence than TD children. We also aimed to analyze whether alexithymia plays a role in expressive incoherence. Our findings show that, compared to TD children, children with ASD have more expressive incoherence in relation to negative behavior occurring with neutral and positive facial expressions but not in positive behavior occurring with negative facial expressions. Additionally, alexithymia moderates de occurrence of positive facial expressions during negative behaviors.

Expressive Incoherence in ASD

In the present study expressive incoherence was conceptualized as a mismatch between the valence of the behavior and the valence of the expressed emotion occurring simultaneously. Following this conceptualization three dyads of behavior and facial expression valences were considered incoherent: negative behaviors co-occurring with neutral

facial expressions, negative behaviors co-occurring with positive facial expressions, and positive behaviors co-occurring with negative facial expressions. We found that overall, even though children with ASD and TD children, were more coherent than incoherent, children with ASD, compared to TD children, had more expressive incoherence than TD children. Comparing groups on the three types of expressive incoherence, we found that children with ASD engaged more in negative behaviors while expressing neutral and positive emotions but that groups did not differ on the amount of positive behaviors co-occurring with negative facial expressions. These results corroborate prior research that found more emotional response incoherence among children with ASD than TD children (e.g. Legiša et al. 2013; McGee et al. 1991).

The present results also expand this area of research by incorporating evidence that emotional response incoherence previously reported in individuals with ASD is not limited to context-dependent incoherence (e.g. Grossman et al. 2013; Yirmiya et al. 1989) or to the facial expression not matching the subjective experience (Legiša et al. 2013; Weiss et al. 2013) but that it also occurs at an intrapersonal level involving responses from the same system (i.e. expression of emotions).

Furthermore, the present results provide evidence that emotional response incoherence in ASD goes beyond the normative emotional response incoherence aimed at benefitting interpersonal relationships. In the present study, children with ASD presented incoherence even in responses that were part of the same system and at a within-individual level. The dual-process frameworks (Evers et al. 2014) posit that responses from the same system, as compared to responses from different systems, should be coherent. Furthermore, paradigms analyzing emotional response coherence at a within-individual level, where coherence is analyzed in terms of which responses coordinate and not in terms of the correlation between different responses' frequencies, have been supportive of emotional response coherence across systems (Cacioppo et al. 1992; Rosenberg and Ekman 1994). Finally, the present data also demonstrate that emotional response incoherence in ASD is not limited neither to a lack of emotional response to a situation nor to difficulties on the self-report of emotions (Ekman 1993).

The Role of Alexithymia in Expressive Incoherence

The second aim of the present study was to analyze if alexithymia plays a role in expressive incoherence in ASD. To our knowledge, the present study is among the few that has examined alexithymia in such a young age group of children with ASD. However, our results are similar to those obtained with older individuals with ASD (e.g. Berthoz and Hill 2005) revealing that parents of children with ASD, compared to parents of TD children, report significantly higher levels of alexithymia in their children. Additionally, we found that after controlling for alexithymia, groups remained different in overall expressive incoherence. Analyzing the effects of alexithymia on the three sub-types of expressive incoherence, we found that groups remained different on the amount of negative behaviors with neutral facial expressions and similar on the amount of positive behaviors with negative facial expressions. However, controlling for alexithymia reduced groups' difference in the amount of negative behaviors with positive facial expressions from a significant to a non-significant level.

Based on the effect of alexithymia on the amount of positive facial expressions displayed during negative behaviors above and beyond group difference, we explored in which way alexithymia influenced the occurrence of this incoherence. We found that alexithymia played a moderating role on this relation. Specifically, we found that children who were reported by their parents as having low levels of alexithymia expressed more positive emotions in situations involving low levels of negative behaviors than in situations involving high levels of negative behaviors. However, children reported by their parents as having high levels of alexithymia expressed as many positive emotions in situations involving low and high levels of negative behavior.

Even though alexithymia only played a role in the explanation of the occurrence of positive emotions during negative behaviors and none in the explanation of the occurrence of neutral facial expressions during negative behavior, these results provide preliminary support for our hypothesis that alexithymia moderates, at least in some situations, expressive incoherence. Alexithymia is characterized by difficulties recognizing, describing, and distinguishing emotions (Sifneos 1973), which can be fundamental abilities for an individual to understand inner states and match emotional responses coherently. Therefore, individuals who have high levels of alexithymia, such as many individuals with ASD, might have more difficulties understanding their emotions and consequently have more difficulties expressing them in a coherent way. This effect might be stronger in situations where children engage in negative behaviors but express positive emotions than when they express neutral emotions. Expressing positive emotions while engaging in negative behaviors might be considered more awkward than expressing neutral emotions and therefore alexithymia may have a stronger effect. Another possible explanation could be that the occasions when children engaged in negative behaviors while expressing positive emotions were more emotionally loaded than the ones when they expressed neutral emotions.

Understanding Emotional Response Incoherence in ASD

Although the present study shows preliminary evidence for the role of alexithymia in expressive incoherence in children with ASD, other possible explanations should be considered. Because rules of emotional response incoherence are taught through socialization (Izard 1990), and children with ASD are known to have difficulties in socialization, it could be that the display rules of different emotional modalities were not learned appropriately. However, the type of incoherence observed in children with ASD is different from the type used for social purposes. Children with ASD, compared to TD children, have more ambiguous and awkward emotional facial expressions and their facial and behavioral expressions are less coherent (e.g. Brewer et al. 2016).

Another possibility is that emotional response incoherence might serve as a regulation strategy to deal with undesired emotions (Huang and Galinsky 2011): voluntarily making a facial expression can generate some of the subjective experience of that emotion (Ekman 1993; Ekman et al. 1983). Therefore, engaging in negative behaviors while expressing positive or neutral emotions could be seen as an attempt to change the emotional impact of the situation. However, this strategy would require high level metacognitive skills that children with ASD are known to have difficulties with (Begeer 2005) and there is also first evidence that individuals with ASD are less sensitive to facial feedback than TD controls (Helt and Fein 2015).

Implications for Assessment and Interventions

The present results suggest some implications for assessment and intervention in children with ASD. Emotional response incoherence is a complex mechanism that is socially learned and can benefit social interactions (Ekman and Friesen 1975). Even though the type of incoherence observed in individuals with ASD seems to be different from the one used for social purposes, its occurrence has been linked to several negative cognitive and well-being outcomes (Niedenthal 2007) as well as to cognitive, affective, and neurological disorders in children (Weinberg and Tronick 1994). Emotional incoherence can also hamper communication: children who send contradictory signals in a social interaction, such as engaging in negative behaviors while expressing positive emotions, might be misunderstood by the communication partner.

With our findings we have provided evidence that children with ASD have more expressive incoherence than TD children and that alexithymia might play a determinant role in at least some types of incoherence. Therefore, one implication from our results is that because emotional incoherence is common among children with ASD, the identification of emotional response incoherence might be important in the assessment of emotional, social, and communication difficulties in these children. Furthermore, children with ASD would benefit from interventions targeting difficulties related to emotional expression and regulation and particularly on display rules and coherence across emotional responses. Another implication from our study, which is linked to the role of alexithymia, underlines the need to consider alexithymia levels on the assessment of emotional difficulties such as expressive incoherence and to provide interventions to help children with ASD recognize, describe, and distinguish emotions.

Limitations and Future Directions

While the present study provides a better understanding of emotional difficulties in children with ASD, there are a few limitations that need to be addressed. A first possible limitation of our study is that due to sample availability restrictions it was not possible to match groups for alexithymia. Matching groups in alexithymia has the advantage of keeping alexithymia effects similar among groups and therefore enables a more accurate account of the shared variance between ASD and alexithymia. However, because alexithymia is approximately five times more common among individuals with ASD than among TD individuals (Berthoz and Hill 2005), matching groups in alexithymia could lead to non-representative sample selection. Nevertheless, future studies should match groups in alexithymia in order to better determine the separate effects of alexithymia and ASD in expressive incoherence.

Another possible limitation concerns the validity of using parent-reports to assess children's alexithymia. Parent-reports represent a promising tool that enables the assessment of processes in low-functioning individuals and young children. In our study, the instrument's reliability proved to be satisfactory. Nonetheless, more research is needed in order to validate the use of parent-reports in order to identify alexithymia in children.

A final limitation of our study is related to the size of our sample and therefore to the restricted estimation accuracy of our regression model. Therefore, our results on the moderation effect of alexithymia in expressive incoherence must be taken as preliminary and further research on the topic is needed. Furthermore, alexithymia effects should also be tested in other aspects of emotional response incoherence. If alexithymia does indeed play a moderating role on emotional response incoherence, its effects should be present across emotional response systems other than the expressive.

Conclusions

Although emotional response incoherence can be normative and help develop interpersonal relationships, it also comes at certain costs. It has been linked to diminished cognitive performance and impaired emotional outcomes (Niedenthal 2007). Emotional response incoherence has also been suggested to have clinical and functional implications and may serve in the identification of emotional and behavior difficulties (Weinberg and Tronick 1994). Our results show that children with ASD, compared to TD children, present more expressive incoherence. Specifically, we found that, compared to TD children, children with ASD tend to engage in more negative behaviors while expressing more neutral and positive emotions. Furthermore, we found that taking alexithymia into consideration eliminated group differences on the occurrence of negative behavior during the expression of positive emotions. Further analyses revealed that alexithymia moderated the relationship between the expression of positive emotions and the use of negative behaviors by creating more incoherence: children with high levels of alexithymia displayed the same amount of positive emotions independently of the level of negative behavior while children with low levels of alexithymia expressed more positive emotions in situations involving low levels of negative behaviors than in situations involving high levels of negative behaviors. Even though these results are preliminary and should be interpreted with caution, they can contribute to the understanding of emotional difficulties in children with ASD.

Acknowledgments This manuscript has not been previously published and is not under consideration in the same or substantially similar form in any other journal. This manuscript is part of a series of manuscripts describing the major findings of a study in emotional reactivity and emotion regulation in children with ASD. Although the different manuscripts will be based on the same dataset, research questions and analyses will be substantially different.

Author Contributions APC conceived of the study, participated in its design and coordination of the study, performed the measurements, participated in the analysis and interpretation of data, and drafted the manuscript; GS participated in the conception and design of the study, interpretation of the data, and in revising the manuscript; ACS participated in the analysis and interpretation of data and in revising the manuscript critically for important intellectual content. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest Andreia P. Costa declares that she has no conflict of interest. Georges Steffgen declares that he has no conflict of interest. Andrea C. Samson declares that she has no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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