Development and Psychophysiological Correlates of Positive Shyness from Infancy to Childhood

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Introduction

Human facial expressions of emotions are supposed to be, already from infancy and in all the cultures around the world, a reflection of our internal emotional states (Ekman, 1994; Izard, 1994; Izard & Malatesta, 1987). From an evolutionary perspective, emotions arise to prepare the organism to react to environmental demands (Darwin, 1872; Ekman, 1992; Izard, 1977; Lazarus, 1991). In social contexts, emotional facial expressions have the function to regulate interactions and to influence the receiver in ways that are beneficial to the sender (Russell, Bachorowski, & Fernández-Dols, 2003). Facial expressions are, thus, an essential aspect of social communication, and difficulties in showing (or understanding) these expressions can impair social relations and possibly lead to abnormal development (Keltner & Kring, 1998; Keltner, Moffitt, & Stouthamer-Loeber, 1995). One of the most fascinating facial expressions is the expression of shyness, which can be displayed through gaze or head aversions produced during a neutral or negative facial expression (negative valence) or during a positive facial expression (positive valence). Shy facial expressions communicate one's concern or worry about being socially exposed to others' attention or evaluations but, at the same time, the wish to remain engaged in the situation and to make a good impression (Asendorpf, 1990; Buss, 1986; Colonnesi, Napoleone, & Bögels, 2014; Reddy, 2000; Schlenker & Leary, 1982). In the present chapter, we illustrate how the facial expressions of shyness

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develop from infancy to childhood and to what extent they are related to specific physiological reactions.

Human expressions of shyness are manifestations of their individual experience of emotions, which can vary based on their temperament (Keltner & Ekman, 2003) and the specific social situation (Colonnesi et al., 2014). In this regard, a distinction should be made between trait and state shyness (Asendorpf, 1989; Crozier, 1990). Trait shyness refers to the individual predisposition or temperamental shyness. Trait shyness is generally indexed through parents' or child's report on questionnaires, and it is based on a deep knowledge of the child's feelings and behavior across situations for a long period of time (Colonnesi, Engelhard, & Bögels, 2010; Crozier, 1995; Russell, Cutrona, & Jones, 1986). Therefore, it is assumed to be a stable characteristic of the child. Empirical evidence shows a modest to moderate developmental stability of trait shyness from infancy to childhood (e.g., Karevold, Ystrom, Coplan, Sanson, & Mathiesen, 2012) and from childhood to adulthood (e.g., Tang et al., 2017). In contrast, state shyness refers to the feeling and expression of shyness that everyone can experience, during a specific event. State shyness is regarded as an interaction among characteristics of the specific social situations, child's temperament or personality, level of self-consciousness, and social coping abilities (Colonnesi, Nikolić, de Vente, & Bögels, 2017). State shyness is usually assessed with experimental procedures eliciting shy reactions (e.g., Colonnesi et al., 2014, 2017; Colonnesi, Bögels, de Vente, & Majdandžić, 2013; DiBiase & Lewis, 1997; Poole & Schmidt, 2019). To date, no empirical study has investigated the developmental trajectories of state shyness from infancy to childhood. Knowledge on the developmental stability of state shyness is paramount to understanding to what extent children expressions of shyness change as a result of development and environmental influences.

The transition from infancy to childhood is probably one of the most interesting aspects of the developmental stability of the expressions of shyness. According to Lewis and colleagues, state shyness is a manifestation of the development of self-consciousness in children (DiBiase & Lewis, 1997; Lewis, Stanger, Sullivan, & Barone, 1991; Lewis, Sullivan, Stanger, & Weiss, 1989). That is, in order to experience a self-conscious emotion, the child needs to develop self-awareness, which is the ability to recognize oneself as an individual separate from the environment and other individuals. Self-awareness is manifested in self-referential behavior, such as the self-recognition in a mirror (i.e., self-recognition task), which emerges around the age of 15–18 months (Amsterdam, 1972). Since self-awareness is not yet developed in the first year of life, infants are expected to be incapable of experiencing and displaying shy emotions (Lewis et al., 1989). Lewis and colleagues also provided empirical evidence about a positive concurrent association between self-recognition and shyness in children older than 12 months, confirming their association only after the first year of life. Similarly, Buss (1986) proposed two different and independent forms of shyness in infancy and childhood: a fearful shyness in infancy, manifested with negative behavior like crying, distress, and other fear reactions, and a self-conscious shyness in childhood, manifested with embarrassment, blushing, disorganized behavior, and cognitive anxiety. A longitudinal study corroborated

Buss' theory, finding no concurrent, nor longitudinal, association between fearful and self-conscious shyness in the transition from infancy to childhood (Eggum-Wilkens, Lemery-Chalfant, Aksan, & Goldsmith, 2015).

An alternative perspective has been proposed by Reddy and colleagues (Draghi-Lorenz, Reddy, & Costall, 2001; Draghi-Lorenz, Reddy, & Morris, 2005; Reddy, 2003). Infants are able, already in early infancy, to interact socially. Hence, Reddy (2005) argued that infants already have a form of pre-awareness of others as attending beings and of the self as an object of others' attention (Reddy, 2003; Trevarthen, 1993). This first form of awareness precedes and shapes the later self-conscious representations. In line with this hypothesis, some evidence of shyness should be observable already in the first year of life, and the expressions of shyness in infancy should be to some extent associated to the expressions of shyness after infancy. Testing the developmental stability of state shyness in the transition between infancy and childhood would shed some light on the possible role of self-awareness in the development of state shyness.

A last crucial aspect in the development of shyness is the association between the expressions of shyness and physiological reactions. As every other emotional state, shyness is accompanied not only by the behavioral component (i.e., facial expression), which serves a social function, but also by physiological reactions, which help the organism to respond to the demands of the environment in adaptive ways (Cannon, 1914; Darwin, 1872). In line with this assumption, physiological arousal should accompany the facial expressions of shyness. In this chapter, the research on the psychophysiology of positive and negative shyness is reviewed and discussed. Because not much research has been done on physiological underpinnings of positive or negative shyness specifically, we will first shortly draw on psychophysiological research of shyness usually defined as a temperamental trait (Buss, 1980; Rubin, Coplan, & Bowker, 2009). Then, we will discuss what physiological underpinnings are expected in positive shyness based on the theory and past research of more adaptive forms of shyness. Finally, we will build on the theory and existing evidence by offering empirical findings from our laboratory on the psychophysiology of positive vs. negative shyness.

Positive and Negative Expressions of Shyness

A fascinating question is when expressions of shyness do appear in human development. Already in the first months of life, infants display positive and negative facial expressions with clear social functions (Colonnesi, Zijlstra, van der Zande, & Bögels, 2012; Messinger & Fogel, 2007). Facial expressions of shyness, called "coy smiles" or "shy smiles," have been observed in early infancy (Colonnesi et al., 2013; Reddy, 2000; Stifter & Moyer, 1991; Young & Décarie, 1977). They are smiles, with closed or open mouth, in combination with gaze aversion, head aversion (downward or sideways), or both (Asendorpf, 1990; Colonnesi et al., 2014; Reddy, 2000). Head aversions during coy smiles appear to be uncontrolled contractions of the muscles directed to decrease or avoid the social contact and to seek protection (e.g., turning to the upper body of the mother when the infant is in the parent's arm). The possible function of head and gaze aversions is to regulate internal states and to reduce arousal by avoiding social contact (Stern, 1974; Stifter & Moyer, 1991). Head aversions are often combined with upper-body aversion or arm rising. Interestingly, although when displaying a coy smile infants break the interaction with the aversion, gaze or head returns are often observed. Doing so, they do not break completely the social interaction (Reddy, 2005).

To our knowledge, Reddy (2000) conducted the first study on positive shyness in early infancy, observing the production of coy smiles in five infants longitudinally (from 7 weeks till 20 weeks) during positive interactions in natural contexts with the parents, a stranger, and the self in a mirror. On average, 21% of the smiles produced by the infants were coy smiles (with gaze aversion, head aversion, or both gaze and head aversions). The first occurrence of coy smiles ranged from 8.4 to 11.1 weeks, and the frequency of production increased with age in four of the five infants. Interestingly, parents reported that after 15 weeks, coy smiles were increasingly directed to strangers. This study established the structural configuration of the facial expressions of shyness in infancy and showed clear morphological similarities between the expressions of shyness in early infancy and those reported in studies with older children and adults. The similarities in the structural configuration between the shy expressions in infancy and in adults was confirmed by the study of Draghi-Lorenz et al. (2005) in which the same videos were rated by independent adult observers who were able to distinguish the shy expressions from the other expressions (e.g., happy, interested, surprised, and upset).

Besides the structural configuration, empirical research has been conducted to investigate the functional similarities between the expressions of shyness in infancy and at later age. In children and adults, shyness is enhanced by interactions with novel persons (Bretherton & Ainsworth, 1974) or when seeing one's own reflection in the mirror (Amsterdam, 1972; Amsterdam & Greenberg, 1977; Lewis et al., 1989; Reddy, 2000). Colonnesi et al. (2013) tested this hypothesis in young infants. The authors systematically observed the production of coy smiles of eighty 4-month-old infants during a series of situations in front of a mirror: seeing only themselves in the mirror, seeing only a familiar (mother, father) or unfamiliar (stranger) person in the mirror, and seeing both themselves and the other person in the mirror. Infants' produced significantly more coy smiles in the situations in which they could see themselves interacting with the social partner in the mirror as compared to the situation in which they could see only the social partner, confirming the finding in adults that shyness is enhanced by one's own mirror reflection because of heightened self-awareness. In addition, as already reported by the parents in Reddy's study (2000), infants produced significantly more coy smiles when they interacted with a novel person than when they interacted with a familiar person or when there was no interaction. The results established functional similarities between the expression of shyness in infancy and at a later age.

Far less investigated in infancy are the negative expressions of shyness. Young and Décarie (1977) distinguished in 9- to 12-month-old infants' two expressions of shyness. The first was the “positive expressions of shyness” (shy smile) in which the eyes may be directed downward during a closed-mouth smile. The second was the “nonpositive expression of shyness” (shy face), in which the eyes are directed downward or sideways, during the absence of smile or with lips slightly retracted laterally and pressed together. These two facial expressions, however, have been never empirically investigated in infancy. In childhood, facial expressions of shyness, especially negative facial expressions, have been generally observed together with verbal and body behaviors in more general coding systems of children’s embarrassment or shy and inhibited behaviors (e.g., movement of the hand to touch part of the body, face or hair, or blushing; DiBiase & Lewis, 1997; Greenberg & Marvin, 1982; Lewis et al., 1989, 1991).

Only a few studies have explored facial expressions of shyness alone in childhood. Colonnesi et al. (2014) observed 2.5-year-olds’ facial expressions of positive and negative shyness during a performance task in which children were asked to imitate the noise of different animals in front of a mirror. The pattern of positive expressions of shyness was analogous to the one found in 4-month-old infants in the study by Colonnesi et al. (2013). Besides, negative expressions of shyness were also observed in toddlers. Negative shy expressions were observed when a gaze aversion, head aversion, or both appeared during a negative facial expression (e.g., frown). The same coding system was used by Colonnesi et al. (2017) and Nikolić, Colonnesi, de Vente, and Bögels (2016) to observe 4.5-year-old children’s shy expressions during a performance task, in which children were asked to sing a song on stage. In both studies, positive and negative expressions of shyness were found to be negatively associated with each other. Colonnesi et al. (2014) suggest that both expressions are likely to serve the purpose to cope with the arousal during social anxiety-provoking situations. Positive shy expressions seem to have, however, a more adaptive function because they reduce arousal without interrupting the social interaction and because they enhance social affiliation (Feinberg, Willer, & Keltner, 2012). Conversely, negative expressions of shyness seem to absolve the short-term function of reducing arousal but can be more maladaptive in the long term reducing social contact and self-confidence (Thompson & Calkins, 1996). Similarly, Poole and Schmidt (2019) recently investigated the expressions of positive and negative shyness in 7-year-old children during a performance task (i.e., self-presentation task). In this study, positive shyness was qualified as high positivity (i.e., smiling, giggling) and high avoidance behavior (i.e., leaning or stepping away from the camera), negative shy as low positivity and high avoidance behavior, and non-shy as low avoidance behavior. The authors found that negative shy children had high levels of social anxiety and lower level of sociability, while positive shy children were equivalent to non-shy children. All together, these findings provide evidence about the heterogeneity of shyness and suggest the presence of two specific subtypes of expressions: positive shyness which is an adaptive way to cope with shy feelings by reducing arousal and enhancing social affiliation and negative shyness, which is a maladaptive form of shyness, related to social anxiety and a low social understanding.

Developmental Stability in the Expressions of Shyness from Infancy to Childhood

Although a series of cross-sectional studies illustrated the structural configurations and functions of the facial expressions of shyness in infancy and childhood, no past studies have investigated the developmental stability of shy expressions. Research shows that temperamental shyness, as reported by parents, presents a moderate stability from infancy to late childhood and appears to be less stable from infancy to childhood and increasingly stable from early childhood to middle childhood (e.g., Asendorpf, 1990; Degnan, Henderson, Fox, Rubin, & Nichols, 2008; Karevold et al., 2012; Pedlow, Sanson, Prior, & Oberklaid, 1993) and from middle childhood to adulthood (Tang et al., 2017). Since the expressions of shyness are regarded as manifestations of temperamental shyness, a similar pattern should be expected.

We combined data of our longitudinal study from 4 to 72 months (Colonnesi et al., 2013, 2014, 2017) in order to test the temporal stability (rank order stability over time) of the positive and nonpositive or negative expressions of shyness from infancy to late childhood. We included data of positive expressions of shyness at 4 months (Colonnesi et al., 2013 and unpublished data), positive and nonpositive expressions of shyness at 12 months (unpublished data), and positive and negative expressions of shyness at 30 months (Colonnesi et al., 2014), 48 months (Colonnesi et al., 2017; Nikolić, Colonnesi, et al., 2016), and 72 months (unpublished data). Participants were 115 children (51 boys and 64 girls). Although different tasks were used during infancy (attention of a stranger), toddlerhood (performance in front of a mirror), and childhood (performance: singing a song for a small public), we always used the comparison data of situations (first 60 s) in which the child obtained the attention of or performed for a novel person (stranger).

Table 1 shows the main characteristics, task used, and coding systems selected in each measurement to test the developmental stability of the expressions of positive and nonpositive shyness across studies. The correlations between positive and neutral/negative shyness at each time were as follows: $r(99) = -0.12$, $p = 0.220$ at 12 months; $r(96) = -0.24$, $p = 0.019$ at 30 months; $r(92) = -0.31$, $p = 0.003$ at 48 months; and $r(78) = -0.08$, $p = 0.484$ at 72 months (based on only four children who displayed negative shyness).

We performed two autoregressive models using structural equation modeling with the software AMOS 25.00 to test the temporal stability of the expressions of positive shyness from 4 till 72 months and of nonpositive shyness from 12 to 72 months. The key feature of the autoregressive model is the regression of a variable on its earlier value, and it is, therefore, a well-suited method for analyzing the stability of observed or latent variables (Bollen & Curran, 2004). Missing data were estimated using the full information maximum likelihood estimation in AMOS. The model for positive expressions of shyness presented a good fit, $\chi^2 = 3.81$, $df = 6$; CFI = 1.00; RMSEA = 0.00, 90% CI [0.00, 0.09]. Figure 1 presents the standardized estimation weights for the model of positive expressions of shyness. Stability was significant in the first year of life (4–12 months) and early childhood (30–48 months)

Table 1 Overview of the longitudinal study

Measurement moment	No. of children	Tasks or subtask	Measures of shyness (coding)	Measures of autonomic arousal
4 months (Colonnesi et al., 2013; unpublished)	119	Interactions in front of a mirror with a stranger	*Positive expressions of shyness (coy smiles)*: number of smiles in which a gaze aversion, a head aversion, or both occurred in the time between 1.5 and 0 s before the apex of the smile	–
12 months (unpublished)	110	Interactions in front of a mirror a stranger	*Positive expressions of shyness (coy smiles)*: number of smiles in which a gaze aversion, a head aversion, or both occurred in the time between 1.5 and 0 s before the apex of the smile *Nonpositive expressions of shyness*: number of neutral or negative facial expressions in which a gaze aversion, a head aversion, or both occurred in a temporal episode of 2 s	–
30 months (Colonnesi et al., 2014)	102	Mimic of animal sounds together with a novel person	*Positive expressions of shyness*: number of positive facial expressions in which an aversion (gaze, head, or both) occurred within 1.5–0.0 s prior to the apex of the smile *Negative expressions of shyness*: number of negative facial expressions in which an aversion (gaze, head, or both) occurred in a temporal episode of 2 s	–
48 months (Colonnesi et al., 2017)	96	Sing a song in front of a small audience (two experimenters and the father)	*Positive expressions of shyness*: number of positive facial expressions in which an aversion of gaze, head, or both occurred within 2–0.0 s prior to the apex of the smile *Negative expressions of shyness*: number of negative facial expressions in which an aversion of gaze, head, or both occurred in a temporal episode of 2 s	Heart rate (HR) Heart rate variability (HRV) Skin conductance (SC) level
72 months (unpublished)	83	Sing a song in front of a small audience (two experimenters and the father)	*Positive expressions of shyness*: number of positive facial expressions in which an aversion of gaze, head, or both occurred within 2–0.0 s prior to the apex of the smile *Negative expressions of shyness*: number of negative facial expressions in which an aversion of gaze, head, or both occurred in a temporal episode of 2 s	Heart rate (HR) Heart rate variability (HRV) Skin conductance (SC) level

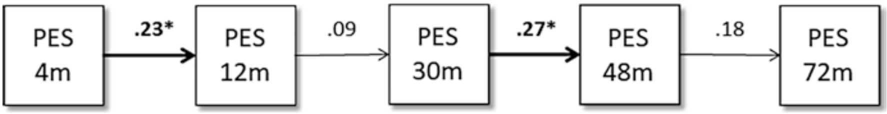

Fig. 1 Autoregressive model testing the expressions of positive shyness (PES) at 4 months (4m), 12 months (12m), 30 months (30m), 48 months (48m), and 72 months (72m)

but not in the transition from infancy to childhood (12–30 months) and from early to later childhood (48–72 months).

A second model was performed for the expressions of nonpositive at 12 months and negative shyness at 30 and 48 months. The expressions of negative shyness at 72 months were too infrequent (i.e., only four children displayed these expressions) to be included in the analysis. Moreover, for this model, we excluded four participants who dropped out after 12 months. The model presented a good fit, $\chi^2 = 0.63$, $df = 1$; CFI = 1.00; RMSEA = 0.00, 90% CI [0.00, 0.21]. Stability between 12 and 30 months was not significant, $\beta = 0.17$, $p = 0.114$, while stability between 30 months and 48 was significant, $\beta = 0.23$, $p = 0.030$. We can, therefore, conclude that the expressions of nonpositive or negative shyness were unstable from infancy to childhood, but they were stable in middle childhood.

Our findings for the facial expressions of shyness are only partially in line with previous results on shyness as a temperamental trait. While shy temperament seems to be moderately stable from infancy to late childhood, the way shyness is displayed via positive or negative facial expressions is not stable in the transition from infancy to childhood and from early childhood to later childhood. The instability in the transition from infancy to childhood can be explained by the development of self-awareness and self-consciousness in the second year of life (DiBiase & Lewis, 1997; Lewis et al., 1989, 1991). From this perspective, the first manifestation of shyness in infancy is only a mere and undifferentiated emotional reaction to others' attention, and it is not determined by self-awareness. Beyond infancy, shyness becomes a self-conscious reaction, displayed in specific situations in which the child experiences the feeling and the awareness of others' attention and possible evaluations. Still, the expressions of shyness in infancy can be, as proposed by Reddy (2000), a form of pre-awareness of others' attention, preceding and shaping the later development of self-consciousness. This can be assumed on the basis of the shared structural (i.e., facial expression configuration) and functional (i.e., reaction to others' attention of self-reflection) features (Colonnesi et al., 2013). A last possible explanation is the assessment of positive shyness. While at 4 and 12 months we used tasks in which the infants were exposed to positive attention of adults (e.g., compliments), at later ages children were asked to perform in a task (i.e., imitating animal noises or singing a song). The lack of an approach-exposure task during childhood did not allow us to test a task-effect hypothesis.

Less expected was the lack of stability of both positive (i.e., no significant association) and negative (i.e., lack of negative expressions) shy expressions from 48 to

72 months. A possible explanation is that later individual socio-cognitive development (e.g., advanced social cognition, social skills) and effortful control are responsible for less frequent and more regulated shy reactions (Karevold et al., 2012; Raffaelli, Crockett, & Shen, 2005). In other words, in later childhood, children's perception and evaluation of social situations, as well as their emotional reactions, become more defined. This determines specific individual developmental trajectories of the expressions of shyness.

Psychophysiology of Positive Shyness

Physiological Underpinnings of Shyness

Shyness is assumed to originate in dysregulation of the fear system (Kagan, Reznick, & Snidman, 1988; Schmidt, Polak, & Spooner, 2005). Because shy children perceive social situations as a threat and fear how others will evaluate and react to them, the fight-or-flight reaction to threat is activated and shy children become hyperaroused in social situations (Kagan et al., 1988; Schmidt, Fox, Schulkin, & Gold, 1999). On the physiological level, peripheral changes, which are innervated by the autonomic nervous system, occur. Specifically, the activation of sympathetic and/or withdrawal of parasympathetic autonomic nervous system arise (Berntson, Cacioppo, Quigley, & Fabro, 1994). This has been referred to as "autonomic hyperarousal." Autonomic hyperarousal is most commonly reflected in peripheral changes such as increased heart rate (HR), reduced heart rate variability (HRV), and elevated skin conductance (SC) levels. Increased HR is thought to be a reflection of both the activation of the sympathetic system and the withdrawal of the parasympathetic system (Kreibig, 2010). Sympathetic responses to a stressor include increased adrenergic activity which causes the heart to beat faster. Besides this sympathetic influence on HR, certain pathways from subcortical structures such as the amygdala to the vagus nerve also influence HR, suggesting parasympathetic influences of HR (Levy, 1971). The reduction in high-frequency heart rate variability (HRV), which reflects variations in time intervals between heart beats, is primarily a result of parasympathetic influences on the heart (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Finally, increased SC is thought to reflect primarily sympathetic activation because sweat glands in the skin are influenced only by sympathetic nerves (Dawson, Schell, & Filion, 2007). Thus, children who experience shyness are expected to show elevated HR, reduced HRV, and increased SC level and response due to their hyperarousal in social situations. Besides the elevated autonomic response in social situations, shy children may display elevated autonomic activity during rest (i.e., during baseline preceding the social situation) suggesting that they are more vigilant and alert than non-shy children, even when a social threat is not present (Kagan & Snidman, 1991).

In terms of elevated HR, one of the first studies on psychophysiology of shy children (Kagan, Reznick, & Snidman, 1987) showed that shy children who are extremely inhibited and cautious in unfamiliar situations have higher heart rate than less inhibited children throughout early childhood. Later studies confirmed this finding. For example, in a study with 7-year-olds (Schmidt et al., 1999), shy children displayed increases in HR as the self-presentation task became more challenging compared with children low in shyness. In another study with children aged 3 years, inhibited children who were slow to start a conversation with a stranger and who showed signs of distress in a situation with unfamiliar people showed higher HR reactivity during a task selected to elicit orienting responses (Scarpa, Raine, Venables, & Mednick, 1997). Also, higher resting HR was found to be related to temperamental shyness in 5-year-old children (Doussard-Roosevelt, Montgomery, & Porges, 2003). Only one study did not find increased baseline HR and increased HR in response to unfamiliar social situations in primary school children (Asendorpf & Meier, 1993). This result may be due to the fact that this study investigated the reactions of shy children in everyday social settings whereas all other studies investigated physiological reactions of shy children in laboratory settings, in situations which involved strangers or scrutiny/evaluation by others. Thus, it may be that shy children are hyperaroused specifically in novel social situations, including either unfamiliar people or scrutiny and evaluation by others.

Besides the increased HR, shy children tend to display reduced HRV as well. For example, shy children who were extremely inhibited and cautious in unfamiliar situations had less variable heart rate throughout early childhood (Kagan et al., 1987). Also, temperamentally shy 5-year-old children showed decreased baseline HRV (Doussard-Roosevelt et al., 2003). However, differences in HRV between more and less shy children in the self-presentation task were not found in a study with 7-year-olds (Schmidt et al., 1999). Thus, past studies offer mixed findings on reduced HRV in shy children.

To date, only one study investigated the association between shyness and skin conductance (SC) in children (Scarpa et al., 1997), showing that inhibited 3-year-old shy children who were slow in starting a conversation with a stranger and who showed signs of distress in a situation with unfamiliar people displayed increased SC reactivity (Scarpa et al., 1997). Although more evidence on increased SC in shy children is lacking, research on constructs closely related to shyness, such as social anxiety, showed that socially anxious children who become easily distressed in social situations and tend to avoid them display the patterns of increased SC during baseline and in socially challenging situations (e.g., Nikolić, de Vente, Colonnesi, & Bögels, 2016; Schmitz, Krämer, Tuschen-Caffier, Heinrichs, & Blechert, 2011).

In sum, most of the past evidence suggests the following pattern of autonomic hyperarousal in social situations in shy children: Both baseline levels and reactivity measures that reflect the activation of autonomic nervous system seem to be heightened in shy children. Of note, in all the above studies, shyness was defined as avoidance and inhibition. However, not all studies that investigated the relations between shyness and autonomic activity in children defined shyness as avoidance and inhibition. For example, regulated shyness, which is defined not as avoidance but the ability to engage and remain in social situations in a nonassertive and unassuming way, has been related to higher HR while interacting with strangers (Xu, Farver, Yu, & Zhang, 2009).

Physiological Underpinnings of Positive and Negative Facial Expressions of Shyness

Similar to temperamental shyness, negative shyness, which is characterized by high avoidance, is expected to be accompanied by autonomic hyperarousal. However, up to date, no study investigated autonomic arousal in negative shyness. Only one study examined the relation between negative shyness and physiological blushing and found no significant relations (Nikolic, Colonnesi, et al., 2016). Unlike negatively shy children who avoid potential social threats, children who express positive shyness are assumed to show not only avoidance but also approach in social situations (Asendorpf, 1990; Colonnesi et al., 2014; Nikolic, Colonnesi, et al., 2016; Poole & Schmidt, 2019). The reason is that they experience social interest, next to feeling nervous and experiencing the motivation to avoid the social situation (Thompson & Calkins, 1996). The question is, then, whether positively shy children experience the same fight-or-flight psychophysiological reaction to socially threatening situations as negatively shy children or whether they react physiologically differently from negatively shy children.

The physiological underpinnings of positive shyness have been largely unexplored so far. In our laboratory, we found that a higher number of positive shy expressions during a social performance task are associated with more physiological blushing in 4.5-year-old children (Nikolic, Colonnesi, et al., 2016). Physiological blushing is assumed to be sympathetically driven response which occurs due to an accumulation of blood in the superficial venous plexus of the facial skin (Drummond, 2012). Therefore, physiological blushing is also, at least partly, under the control of the autonomic nervous system. However, unlike the measures of HR, HRV, and SC, physiological blushing is not typically assumed in the fight-or-flight response, but rather, it is assumed to appear when a child experiences a high level of ambivalent arousal (Nikolic, Colonnesi, et al., 2016; van Hooff, 2012). Just as positive shyness, physiological blushing may be seen as a result of the motivational conflict to approach and avoid social situations at the same time. Indeed, our study confirmed this idea by showing that positive shyness is related to physiological blushing (Nikolic, Colonnesi, et al., 2016). In this study, children were put in a socially challenging situation in which they were asked to sing a song on stage dressed up as "pop stars" in front of a small audience while being video-recorded. The findings showed that children's production of positive expressions of shyness was positively associated with blushing in the same situation. As this result did not occur for negative shyness, it may be that physiological blushing may be specific to positive shyness.

Besides physiological blushing, other indices of sympathetic activation, such as elevated HR and increased SC, may be expected in positively shy children. However, evidence on these physiological markers in positively shy children are currently lacking; thus, we do not know whether sympathetic activation indeed accompanies positive shyness. In addition, the influence of the parasympathetic system in positive shy behaviors is also currently unexplored.

A positive association between positive shyness and indices of the parasympathetic system such as HRV can be expected because children who have a higher baseline and a higher decrease in HRV are better able to regulate their emotions (Appelhans & Luecken, 2006; Porges, 1995). Assuming that positive shyness is an adaptive mechanism which helps children regulate their arousal in socially challenging situations (Colonnesi et al., 2014; Nikolic, Colonnesi, et al., 2016), one can assume that, unlike negatively shy children, positively shy children would be characterized by higher baseline HRV, which reflects a higher capacity for emotion regulation. Moreover, positively shy children can be hypothesized to have higher decreases in HRV during socially challenging situations, as this reflects better emotional coping. Two studies investigated approach and avoidance tendencies in relation to HRV in infants and young children. They found that baseline high-frequency HRV, indexed as respiratory sinus arrhythmia, was related to the tendency to approach a stranger and novel objects (Fox & Stifter, 1989; Richards & Cameron, 1989). Based on these findings, it may be expected that positively shy children, who are characterized by strong motivation to approach in social situations, display high levels of baseline HRV.

Empirical Evidence on the Physiological Underpinnings of Positive and Negative Shyness

Although there is some evidence that may suggest increased HR in positive shyness (Xu et al., 2009), it is still unclear how positive shyness relates to other measures of autonomic arousal, such as HRV, which is assumed to reflect the activation of the parasympathetic branch of the autonomic nervous system, and SC, which is an index of the activation of the sympathetic branch of the autonomic nervous system. Even more important, it is unclear how positive shyness and physiological measures relate to each other longitudinally, predicting and reinforcing each other across child development. This knowledge would allow us to better understand the nature of positive shyness and the physiological factors that may influence its development.

In the longitudinal study conducted in our laboratory in which we followed shyness from infancy to late childhood, we also measured HR, HRV, and SC levels as indices of autonomic hyperarousal at 48 and 72 months. We were, thus, able to examine how the indices of autonomic nervous system relate to, predict, and are predicted by positive shyness from infancy to later childhood. For comparison, we also report on the associations between physiological indices and negative shy expressions.

All physiological measures were recorded and analyzed with the Vsrrp98 software (Molenkamp, 2011) on a personal computer running Windows 7. The actual data acquisition in the program was performed by a National Instruments NI6224 data-acquisition card sampling at a rate of 200S/s per channel. ECG was recorded using a standard Lead-II configuration. R-waves were automatically detected and corrected for artifacts. Two parameters were computed: HR was calculated as the number of R-waves per minute, and HRV was calculated as the square root of the mean squared differences (RMSSD) of successive normal-to-normal (NN) intervals—a commonly used HRV measure (Malik, 1996). Skin conductance level was recorded with two curved Ag/AgCl electrodes placed on the middle phalanx of the middle and index finger of the child's left hand. We measured HR, HRV, and SC during a 2-min baseline preceding the social performance task and the first 30 s of the social performance task. Therefore, we report on six models that examine positive shyness and six models that examine negative shyness in relation to baseline of HR, HRV, and SC and reactivity of HR, HRV, and SC ($n = 105$). To calculate reactivity, we subtracted the mean of 2-min baseline from the mean of the first 30-s of the performance.

We built on the auto-regressive models reported above by adding the physiological indices at 48 and 72 months. Thus, for shyness, we modeled the regression of a variable on its earlier value, and we estimated all the paths to autonomic indices concurrently and longitudinally at 48 and 72 months. Missing data were estimated using the full information maximum likelihood estimation. All the path models fitted the data well according to χ^2, CFI, and RMSEA (ranges positive shyness: $\chi^2 = 4.72–10.43$ ($df = 12$), $p = 0.578–0.967$, CFI = 1.00, RMSEA = 0.00–0.00, 90% CI [0.00, 0.09]; ranges negative shyness: $\chi^2 = 2.06–8.14$ ($df = 5$), $p = 0.149–0.840$, CFI = 1.00, RMSEA = 0.00–0.08, 90% CI [0.00, 0.17]). In the model in which we investigated the relations between positive shy expressions at 4, 12, 30, 48, and 72 months and HR levels during baseline at 48 and 72 months, only one significant relation occurred: positive shyness at 48 months predicted lower baseline HR at 72 months, $\beta = -0.26$, $p = 0.021$. In the model with HR reactivity, one significant relation occurred as well; a larger increase in HR during performance at 48 months predicted more positive shyness at 72 months, $\beta = 0.34$, $p = 0.003$. These findings suggest that children who show positive shyness in early childhood are less alert and less oriented to a possible threat in resting states (baseline) later in their childhood, which is opposite to what has been found in temperamental shyness (Doussard-Roosevelt et al., 2003). However, the increase in autonomic activity at 48 months predicted more positive shyness at 72 months, suggesting that perceiving social situations as a threat may contribute to becoming more positively shy later in childhood. No significant relations between positive shyness and SC levels were found in the model in which we investigated the relations between positive shy expressions at 4, 12, 30, 48, and 72 months and SC levels in baseline at 48 and 72 months. Regarding the model with SC reactivity, one significant relation occurred—more positive shyness at 48 months predicted less SC reactivity at 72 months, $\beta = -0.24$,

p = 0.046. This finding suggests that, similarly to the finding with baseline HR, being positively shy in early childhood contributes to less autonomic arousal in social situations later in childhood.

In Fig. 2a, the relations between positive shy expressions and HRV during baseline are presented, and in Fig. 2b, the relations between positive shy expressions and HRV reactivity are shown. As can be seen from Fig. 2a, more positive shyness at 48 months predicted higher baseline HRV at 72 months, $\beta = 0.26$, $p = 0.018$. Also, higher baseline HRV at 48 months showed a trend toward predicting more positive shyness at 72 months, $\beta = 0.23$, $p = 0.064$. Thus, more positive shyness is related to a better capacity to regulate emotions. It seems that displaying positive shy expressions is adaptive, fostering better physiological emotion regulation later in childhood. Also, better physiological emotion regulation in early childhood contributes to displaying more positive shyness later in childhood. Thus, it seems that positive shyness and physiological emotion regulation reinforce each other throughout childhood.

Regarding the model with HRV reactivity (Fig. 2b), a higher decrease in HRV during the performance at 48 months predicted a higher number of positive shy expressions at 72 months, $\beta = -0.29$, $p = 0.011$. A higher decrease in HRV during

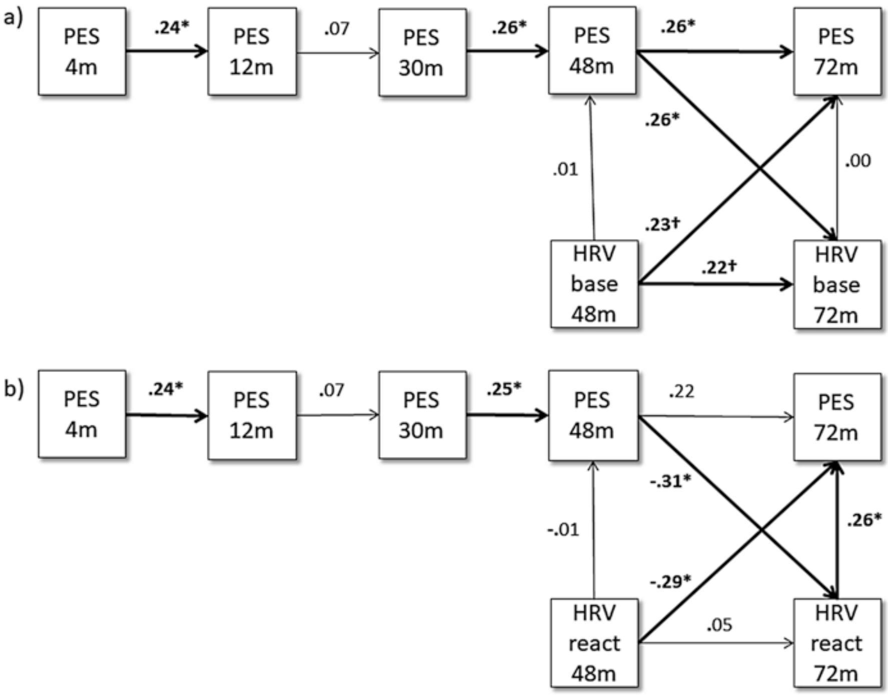

Fig. 2 Associations between expressions of positive shyness (PES) at 4 months (4m), 12 months (12m), 30 months (30m), 48 months (48m), and 72 months (72m) and (**a**) baseline HRV and (**b**) HRV reactivity at 48m and 72m

challenging situations relative to baseline is indicative of good emotion regulation in that particular situation (Porges, 2003; Shahrestani, Stewart, Quintana, Hickie, & Guastella, 2014). The reason is that the decrease in HRV reflects the withdrawal of the parasympathetic branch of the autonomic nervous system during challenging situations allowing the sympathetic activation and active coping with the challenge (Porges, 2003). Therefore, our findings show that children who are able to better cope with the challenging performance situation at 48 months also display more positive shyness later in their childhood. Next to the finding that the stronger decrease in HRV during performance predicts later positive shyness, we also found that positive shyness at 48 months predicts higher reduction in consequent HRV reactivity, $\beta = -0.31$, $p = 0.011$. Therefore, we again found that good physiological emotion regulation and positively shy expressions during socially challenging tasks reinforce each other.

In sum, children who display frequently positively shy expressions at 48 months show better capacity for emotion regulation (indexed as higher baseline HRV) and better actual coping with the challenging performance situation (indexed as decrease in HRV during performance relative to baseline) at 72 months. One unexpected finding occurred regarding positive shyness and HRV at 72 months. Higher number of positive shy expressions was related to a smaller decrease in HRV during performance at the same time. Although this result was not expected, it may be explained by the assumption that positive shyness is an adaptive social strategy long term, but maybe not short term. That is, children who express positive shyness may be aroused in the same moment, but because they remain in the social situation, they get positive feedback from others, build self-confidence, and are able to better cope with similar situations in the future (Nikolic, Colonnesi, et al., 2016).

We also investigated the relations between HR, HRV, SC, and negative shyness in our study. In the model with negative shyness and baseline HR as well as in the model with negative shyness and HR reactivity, no significant relation between negative shyness and HR occurred. This was also the case for the models with baseline HRV and HRV reactivity. In the model with negative shyness and baseline SC, no significant relation was found. In the model with SC reactivity, only one path that showed a trend toward significance was found—more negative shyness at 48 months was related to higher SC reactivity at 72 months, $\beta = 0.23$, $p = 0.060$. This was expected as avoidant and inhibited children are assumed to react with higher sympathetic arousal in social situations (Scarpa et al., 1997). The null findings regarding negative shyness and the indices of autonomic arousal are unexpected, considering that, similarly to temperamental shyness, we would expect that children who display negative shyness perceive social situations as a threat and their fight-or-flight system activates preparing them to flee from and avoid social situations. This was indeed shown in the small effect with increased SC reactivity, but not in HR and HRV, suggesting that negative shyness may be dominantly a sympathetically and not parasympathetically driven phenomenon.

In summary, positive shyness seems to be related to good physiological emotion regulation indicated by high baseline HRV and a strong decrease in HRV in a challenging situation relative to baseline. This finding confirms the notion that positive shyness seems to be an adaptive emotion regulation strategy in challenging social situations (Colonnesi et al., 2014; Nikolic, Colonnesi, et al., 2016). It allows the child not only to deal with the current challenging situation, but it also reinforces adaptive physiological emotion regulation later in child development. On the other hand, we did not find evidence for sympathetic activation (i.e., increased SC levels) in positive shyness. We actually found the opposite—positive shyness was related to decreased SC reactivity. Therefore, it seems that positive shyness has different physiological underpinnings from negative shyness. Unlike positive shyness, negative shyness seems less adaptive. Children who display negative shy expressions are those who seem to be hyperaroused (high SC reactivity) in socially challenging situations.

Conclusion

Recent theoretical and empirical work shows that the expressions of shyness, which reflect the approach-avoidance conflict in social situations, can be already observed in the facial expressions of babies (Colonnesi et al., 2013; Reddy, 2000) and children (Colonnesi et al., 2013, 2014, 2017; DiBiase & Lewis, 1997; Poole & Schmidt, 2019) and can have positive or negative structural and functional configurations (Colonnesi et al., 2013, 2014, 2017). In this chapter, we examined (1) the developmental stability of positive and negative shyness and (2) the physiological correlates of positive and negative shyness. Our empirical results provide evidence for the stability of positive shyness in infancy, and then again in early childhood, but not in the transition from infancy to early childhood and from early childhood to late childhood. A similar pattern was found for the expressions of negative shyness. When looking at the physiological underpinnings of positive and negative facial expressions of shyness, we found that positive and negative shyness have different physiological correlates. Specifically, positive shyness in early and late childhood was found to be related to higher baseline HRV levels and higher decreases in HRV during socially challenging tasks, indicating that positively shy children have well-developed emotion regulation system. This finding strengthens the theoretical assumption that positive shyness is an adaptive mechanism to regulate arousal in social situations (Colonnesi et al., 2014; Nikolic, Colonnesi, et al., 2016). Regarding negative shyness, elevated baseline SC levels indicated higher sympathetic arousal in negatively shy children. Thus, negative shyness seems to be a less adaptive strategy to cope with social arousal.

Developmental instability of shyness can be related to children's individual differences in their socio-cognitive development. In the transition from infancy to childhood, and from early to late childhood, there is a significant development of children's social awareness and cognition (e.g., self-consciousness; DiBiase & Lewis, 1997; Lewis et al., 1989, 1991; Theory of mind; Colonnesi, Rieffe, Koops, & Perucchini, 2008), determining more consistent representations of the self and others during social interactions and, as a consequence, better emotional reactions.

For instance, children with a low level of theory of mind have been found to display more negative shyness, while children with a high level of theory of mind have the tendency to display more positive shyness (Colonnesi et al., 2017; see also MacGowan, Colonnesi, Nikolic, & Schmidt, 2019). Moreover, in both transitions, social experiences, such as interactions with parents and peers, play a role in the socio-cognitive development and are, at the same time, influenced by newly acquired self-awareness and socio-cognitive skills. The interplay between social experience and development of self-awareness might, thus, contribute to the instability in positive and negative shyness that arises in the transition from infancy to early childhood (Carpendale & Lewis, 2004).

Developmental instability in the expressions of shyness can also be related to individual developmental changes in the ability to regulate emotional arousal and more specifically the capacity to regulate social fear (Colonnesi et al., 2014, 2017; Poole & Schmidt, 2019). That is, positive social experience with significant adults and peers can impact the development of emotion regulation and related behavioral manifestations such as more adaptive expressions of shyness. For instance, in the transition from infancy to childhood, children's shift from behaviors directed toward a primary attachment figure to an internalized model of attachment (i.e., internal working model) is based on trust in others, feelings of being accepted, and self-perceived value (Bowlby, 1969). The acquired internal working model, in combination with socio-cognitive development, can shape children's way to cope with social arousal-eliciting situations (Nolte, Guiney, Fonagy, Mayes, & Luyten, 2011). In conclusion, the lack of stability in the expressions of shyness can result from the interplay between individual social-emotional maturation and social experiences.

Regarding the relations with autonomic activity, only positive shy expressions showed multiple associations with the indices of autonomic activity, both with the indices reflecting the activity of the sympathetic and the indices reflecting the activity of the parasympathetic nervous system. Negative shy expressions, however, were not strongly related to autonomic indices and showed only one trend toward a significant association with SC, which reflects the activity of the sympathetic system. These findings suggest that positive shyness, which is accompanied by both sympathetic activation and parasympathetic withdrawal, is a combination of high arousal and high capacity to regulate the arousal. Positively shy children, although hyperaroused, are able to remain in threatening social situations, possibly because they are also able to physiologically regulate their arousal. It may be this ability that allows positively shy children to gain experience and self-confidence in social situations and to develop their regulation capacities even better later in childhood. Unlike positively shy children, negatively shy children are also aroused in social situations but lack the ability to regulate their arousal; thus, they do not remain in situations but avoid them and do not develop regulation capacities as much as positive shy children do.

In conclusion, the way children express shyness depends on children's levels, and regulation, of arousal. Although their structural and functional configurations remain the same, the propensity to express these emotions changes across development. Future research should further investigate environmental and psychoneurological factors that can affect individual differences in the expressions of positive and negative shyness. Clinical implications concern the application of more specific interventions for shy and socially anxious children. That is, knowing that negatively shy children lack emotion regulation capacities, efforts to help them overcome their negative shyness may focus on emotion regulation strategies. Positively shy children do not appear to need such help, considering that their shyness seems to be adaptive and contributes to good emotion regulation later in childhood.

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