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Contagious Yawning in Autistic and Typical Development

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The authors tested susceptibility to contagious yawning in 120 children, 1–6 years, to identify the time course of its emergence during development. Results indicated a substantial increase in the frequency of contagious yawning at 4 years. In a second study, the authors examined contagious yawning in 28 children with autism spectrum disorders (ASD), 6–15 years. Children with ASD showed diminished susceptibility to contagious yawning compared with 2 control groups matched for mental and chronological age, respectively. In addition, children diagnosed with Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS) a milder variant of autism, were more susceptible to contagious yawning than were children diagnosed with full Autistic Disorder. The authors explore the implications of these findings for theories about the development of mimicry and emotional contagion.

Contagion refers to the tendency of a particular behavior to spread through a group in a ‘‘chain reaction.’’ The behaviors that most often trigger contagious reactions in others are those that signify the inner states of others (Hatfield, Caccioppo, & Rapson, 1994). For example, infants in hospital nurseries begin to cry when they hear other babies crying (Hoffman, 1978; Simner, 1971), and laugh tracks accompany most television situational comedies because hearing the laughter of others prompts our own laughter (Bush, Barr, McHugo, & Lanzetta, 1989; Provine, 2000). Similarly, seeing another person yawn, thinking about yawning, reading the word *yawn*, or even hearing the word can elicit a yawn in 40%–60% of normal adults when exposed to such stimuli under experimental conditions (Baenninger & Greco, 1991; Platek, Critton, Myers, & Gallup, 2003; Provine, 1989). Such forms of behavioral contagion may reflect or facilitate *emotional contagion*, which refers to the tendency of individuals to converge emotionally with those around us. The property of contagion, as applied to emotions, offers psychologists an opportunity to study the roots of automatic social behaviors that potentially lay the foundations for the development of empathy.

At least one mechanism by which emotional contagion comes about is via the underlying processes of *mimicry* and *afferent feedback* (Hatfield et al., 1994). Whereas imitation involves the conscious, effortful reproduction of another's behavior, mimicry refers to nonvolitional ‘‘matching’’ behavior (Want & Harris, 2002). As we interact with someone, we often subconsciously mimic (often at a level undetectable to the naked eye or ear) their facial expressions, bodily postures, and speech patterns (see Niedenthal, Barsalou, Ric, & Krauth-Gruber, 2005, for a review).

When a person mimics, the activation of his or her emotional body schemas also creates an emotional reaction that corresponds to the movements being mimicked (i.e., the act of smiling causes us to feel happier). This was first known as *facial* feedback (Capella, 1993), but research has now documented similar effects for gesture, posture, and vocal prosody (see McIntosh, 1996, for a review), and so may be more accurately referred to as *afferent feedback* (Hatfield et al., 1994). The coupling of our automatic tendency to mimic others and the effects of afferent feedback on our own emotional

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states may explain the ubiquity of emotional contagion: Because we unconsciously match the emotional movements of others, we unconsciously feel the emotions of others as we interact with them. Similarly, this account of mimicry may explain its psychological utility: Emotional contagion may allow human beings to intuit the feelings of those around us when we interact socially (Rogers & Williams, 2006).

Yawning is a type of mimicry in that it is a matching behavior that is produced unconsciously. The robust effects for contagious yawning found by Provine et al. (1986) when they exposed participants to videos of people yawning disappeared when the participants knew they were being watched (Provine, 2005), supporting the idea that contagious yawning is an unconscious process that may actually be suppressed by conscious awareness. However, contagious yawning appears to be a special kind of mimicry. Unlike the miniscule muscular movements, often undetectable to the naked eye, that mimicry typically entails, yawns—large, obvious sequences of movements, difficult to stop once initiated and lasting for up to 10 s—are a very visible result of such mimicry. The explanation for this may derive from the fact that yawning is a *fixed action pattern* (Provine, 1986). A fixed action pattern is a species-typical behavioral sequence that is indivisible and, once initiated, runs to completion. Fixed action patterns are invariant and are triggered by a neural network called the ''innate releasing mechanism'' in response to a ''sign stimulus'' or ''releaser'' (in this case, the yawns of others act as an innate releasing mechanism; Tinbergen, 1951). Perhaps the phenomenon of *contagious* yawning can be explained by the idea that mimicking the first part of a fixed action pattern (as would be expected if one were mimicking the facial expressions or vocalizations of a conspecific as he or she begins to yawn) is likely to trigger the release of the entire behavior.

In addition to being a form of mimicry, contagious yawning appears to involve an emotional component. Deputte (1994) identified two contexts for yawns: the ''rest yawn'' observed when the context involves a change in arousal level, and the emotion yawn (which he noted could also be referred to as a ''social yawn''). He defined the emotion yawn as an action used as an unconscious communication of psychological decompression after a state of high alert. Yawning is also similar to the other highly contagious acts of crying and laughing, both of which represent emotional states, in that it produces a distinct sound, as well as a distinct facial expression (Provine, 1996). The existence of an emotion yawn suggests that contagious yawning may be considered a form of emotional contagion. On the other hand, yawning may not signal an emotion but may simply be a facial expression that is unintentionally mimicked, as are other nonemotional facial expressions (Heyes, 2001). If so, then its contagiousness may simply be a by-product of ubiquitous facial mimicry, perhaps evolutionarily adaptive because it facilitates contagion of ''true'' emotions. In either case, the disruption of mimicry, which may be demonstrated by a disruption in contagious yawning, should have consequences for emotional resonance with others. Indeed, empathetic people exhibit greater amounts of all forms of mimicry (Chartrand & Bargh, 1999) and are reportedly more susceptible to contagious yawning (Platek et al., 2003).

Development of Mimicry, Emotional Contagion, and Contagious Yawning

Some capacity for mimicry and emotional contagion appears to be present from birth. Infants as young as 3 hr old execute some behaviors after witnessing them modeled by an adult (Meltzoff & Moore, 1977), most reliably, tongue protrusion (for a review, see Rogers, 2006). Similarly, a case has been made for the presence of emotional contagion from the first days of life; specifically, newborn infants will cry when they hear other babies crying in the nursery, but not in response to computer-generated sounds matched for acoustic properties (Simner, 1971). According to one point of view, newborn ''matching'' behaviors are early examples of the strong link between the *perception* of actions and emotions in others, and the *experience* of these actions and emotions in ourselves, thus setting the stage for imitative abilities that emerge later and underlie critical aspects of social and emotional development. However, early mimetic behaviors and contagious crying gradually become less frequent after birth. Imitative tongue protrusion disappears by 2–3 months (Abravanel & Sigafoos, 1984), and whereas 84% of newborns exhibit contagious crying, only 24% of 3- to 12-month-old infants do so (Bühler & Hetzer, 1928). In place of full-blown contagious crying, infants at 10–14 months are much more likely to mimic the distressed facial expressions of other crying children (Zahn-Waxler, Radke-Yarrow, & King, 1979). Given these decreases in matching behaviors after 2–3 months, it is unclear whether these early behaviors are continuous with later developing capacities for mimicry and emotional contagion. Mimicry and emotional contagion seem to ''reappear'' during the second half of the 1st year and then continue to expand thereafter. For example, by 9 months, babies take on the basic moods and facial expressions of their caregivers, such as joy and sadness (Termine & Izard, 1988). A longitudinal study by Jones (1996) found that mimicry of distinct actions appeared at distinct periods in development between 6 and 18 months.

Spontaneous yawning (termed the ''rest yawn'' according to Deputte, 1994) begins in utero. In contrast, the limited data on contagious yawning (presumably, the emotion yawn) hint that it may not emerge until much later in development. Piaget (1951) reported that his own children did not begin to yawn contagiously until the 2nd year of life. A more recent study suggested an even later age of emergence for contagious yawning, reporting that only children 5 years and older yawned in response to videos of yawns (Anderson & Meno, 2003). Children respond to live stimuli well before they respond to video stimuli (Troseth & deLoache, 1998), and so in vivo yawning may be a more effective stimulus for eliciting contagious yawning in younger children. Furthermore, the instructions in the Anderson and Meno (2003) study required participants to clap whenever they witnessed a yawn. Clapping is an arousing activity, and increased arousal is associated with diminished yawning (Provine, 2005). In addition, the clapping instructions drew conscious attention to yawning, which has also been shown to diminish yawning (Provine, 2005). For all these reasons, the extant results must be interpreted with caution. Therefore, there are few data to address the developmental course of contagious yawning in typical development.

Mimicry, Emotional Contagion, and Contagious Yawning Deficits in Individuals With ASD

Consistent with the hypothesis that mimicry facilitates emotional contagion (Hatfield et al., 1994), children with autism spectrum disorders (ASD) show deficits in both. McIntosh, Reichmann-Decker, Winkielman, and Wilbarger (2006) found that, unlike controls, adults with high-functioning autism did not unconsciously copy the facial expressions of individuals viewed on a video screen (despite being able to imitate them when asked). Meanwhile, children with ASD have been found to be less susceptible to emotional contagion when provided with prompts that typically elicit emotions that match those of the model: for example, an experimenter opening a box in a child's presence and looking delighted or afraid (Scambler et al., 2006) or an experimenter injuring herself (Bacon, Fein, Morris, & Waterhouse, 1998).

One study has examined contagious yawning in children and adolescents with diagnoses including Autistic Disorder, Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS), and Asperger's disorder. Participants with ASD were less susceptible than age-matched typically developing (TD) peers to contagious yawning when exposed to video recordings of people yawning (Senju et al., 2007). Results are difficult to interpret, however, because the ASD group had a lower mental age, and included fewer females, and because of the use of video rather than live models. Given that all these factors could potentially play a role in mimicry, further data are needed to clarify the dimensions of the relative susceptibility of individuals with ASD to contagious yawning.

Current Studies

Study 1 explored the chronological and mental ages at which contagious yawning is exhibited in typical development to provide clues about psychological mechanisms underlying this phenomenon. The study delivered yawning stimuli in an implicit paradigm (i.e., no instructions were given regarding yawning) by a live model, and study procedures were the same for all children—design factors intended to maximize sensitivity to the phenomenon. If contagious yawning is a primitive mimetic response, like contagious crying, it should be evident in the youngest members of the sample. In this case, its reduction or absence in individuals with ASD would imply that basic building blocks of social connection may be abnormal from birth. In contrast, a protracted emergence of contagious yawning would be consistent with the idea that mimicry becomes more ubiquitous and/or fine-tuned as development proceeds. In this case, diminished yawning contagion among individuals with ASD would seem to be a reflection of their diminished implicit social and emotional learning and experience.

Study 2 sought to measure the rates of contagious yawning in a group of children with ASD. This study provided more rigorous diagnosis than Senju et al. (2007), via use of the Autism Diagnostic Observation Scale (ADOS; Lord et al., 2000), excluding children with Asperger's disorder (a variant of the disorder in which language is not affected and potentially involving distinct neural systems; Goodman, 2005), and using live, rather than videotaped, stimuli. In addition, the study sought to examine whether these group differences could be accounted for by differences in mental age, gender, symptom profile, or diagnosis.

Study 1

Method

Participants

Participants were 123 TD children, ages 1–6 years (approximately 20 at each year of age studied), recruited through two local day-care centers. Parents, teachers, and day-care workers were asked to report any known or suspected developmental difficulties for each child. For children age 2 and above, parents or teachers completed the Behavioral Assessment System for Children, Second Edition (BASC–2; Reynolds & Kamphaus, 2004) to screen for any developmental problems. The data of 3 children were excluded—one due to concerns about Tourette's syndrome, one due to coding problems, and one due to lack of attention —for a final sample of 120 children. Sex distribution varied for each year of age with approximately 57% (n = 68) of the total sample being female (see Table 1 for gender breakdown by age). The ethnic background of this group was as follows: 3 children were African American, 5 children were Asian, 32 children were Latino, 3 children were multiethnic, and 80 children were Caucasian.

Procedure

A letter describing the study and obtaining consent was sent home to parents. Parents were asked to either fill out a BASC–2 for their child or give permission for the child's teacher to fill out a BASC–2 for the child. Children whose parents consented to the study were taken individually from their classrooms into a quiet room, seated across from the experimenter. After introducing herself and explaining, ''Now we're going to read some stories together, and then you can pick a prize from this basket'' and showing the child the various toy prizes, the experimenter read aloud one to four stories (depending on the child's age and the complexity of the stories) for a total reading time of approximately 12 min (sometimes with a brief break, again dependent upon the child's developmental level). During the first 2 min of reading, the experimenter did not yawn at all. This, in addition to the first few minutes of introductions before reading, was to control for any changes in arousal level that may have occurred when the children sat down to listen to a story. During the last 10 min of reading, the experimenter paused four times to yawn and discreetly recorded on a coding sheet when a child yawned. Approximately 40% of the sessions (49 of 120), randomly selected, were videotaped and coded by two independent raters (who had not assisted in data collection) for reliability.

For coding purposes, contagious yawns were defined as yawns occurring within 90 s of the yawning stimulus. Although subconscious reactions typically occur much more rapidly, previous reports of contagious yawning (e.g., Provine, 2005) indicate that contagious yawning reactions may be somewhat slower and we wanted to allow for the most liberal possible estimate of the phenomenon, as well as for the possibility that yawning contagion may be mediated by some cognitive processes. Because contagious yawning is a low base rate phenomenon, yawning was coded as a dichotomous

Table 1
Characteristics of Sample in Study 1

	1–2 years (n = 20)	2–3 years (n = 20)	3–4 years (n = 20)	4–5 years (n = 20)	5–6 years (n = 20)	6–7 years (n = 20)
Chronological age (months)						
M	18.1	29.6	41.7	53.2	65.8	79
SD	3.1	3.2	3.3	3.2	3.3	3.5
Range	13–23	24–35	36–47	48–58	61–71	72–83
Visual attention scores (possible range 1–16)						
M	13.2	13.7	14.25	14.65	15.1	14.6
SD	1.4	1.26	1.3	1.01	0.91	0.99
Range	12–16	12–16	12–16	12–16	13–16	13–16
Gender (% female)	60%	55%	55%	55%	60%	55%

variable (present or absent) rather than a measure of yawning frequency (number of yawns total). (Analysis of yawning frequency in all statistics examined in Studies 1 and 2 did not yield a different pattern of results.) Children were considered to be contagious yawners if they yawned in response to at least one of the experimenter's four yawns within a 90-s window. (Yawns occurring outside the 90-s window were exceedingly rare, with only two occurring over the 196 videotaped trials.) Coding criteria required the presence of all of the physical manifestations of a yawn (Provine, 2005): open mouth, narrowed eyes, and an indrawn breath. The data of one 3-year-old girl had to be excluded because she covered her mouth and made a sighing sound but her eyes did not narrow at all. Thus, neither the experimenter nor the research assistants were able to determine whether the child was pretending to yawn in order to imitate the experimenter or was truly yawning. Interrater reliability was 100%, when the one ambiguous responder was removed.

Videotaped sessions were also coded for children's looking behavior toward the experimenter during the 10-s segment in which the yawns were presented by assigning each child a rating of 1 *(not looking at all)*, 2 *(looking for less than 5 s of the 10 s block coded)*, 3 *(looking for 5 or more seconds of the 10 s block coded)*, or 4 *(looking throughout the 10 s block in which the yawn stimulus was presented)* for each of the four trials, resulting in a visual attention score of 1–16 for each child. The data of children with scores of less than 12 ($n = 1$ in Study 1) were excluded from analysis.

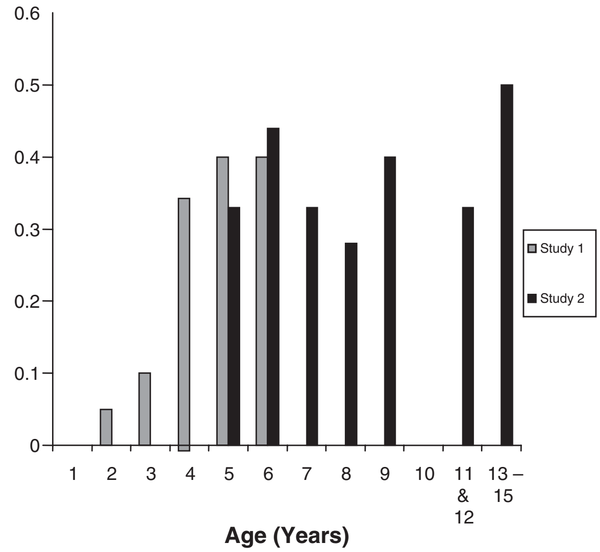

Figure 1. Proportion of contagious yawning by chronological age in typically developing children, Study 1 (children 1–6 years) and Study 2 (children 5–15 years).

Results and Discussion

Results showed that, when exposed to the yawns of a live model over four trials, the proportions of children in each age group who yawned contagiously for at least one trial were as follows: 0% (0/20) of 1-year-olds, 5% (1/20) of 2-year-olds, 10% (2/20) of 3-year-olds, 35% (7/20) of 4-year-olds, and 40% (8/20) of both 5- and 6-year-olds (see Figure 1). Binary logistic regression revealed a significant effect for age, $\chi^2(1, N = 120) = 22.254$, $p < .001$, but not for visual attention, $p = .22$, or gender, $p = .37$, in predicting whether or not a child will yawn contagiously at least once across the four trials of the experiment, with each year of age increasing the odds of contagious yawning by a factor of 2.2. However, the data suggest that these variables do not have a linear relation. Thus, age was recoded dichotomously as ''under 4 years'' or ''4 years and over,'' $\chi^2(1, N = 120) = 22.69$, $p < .001$, revealing that being 4 years or older increased each child's odds of yawning contagiously by a factor of 14.7 (visual attention and gender remained insignificant).

Although the older children appeared to make more sustained eye contact in the direction of the experimenter's face and the book throughout the session, the experimenter yawned when she had each child's attention, resulting in good visual attention to the yawns from all age groups (see Table 1). The amount of visual attention that children directed toward the examiner's face was examined in one-way analysis of variance. There was a statistically significant difference in visual attention scores for the six age groups, $p < .01$. Post hoc comparisons indicated that the mean attention score for 1-year-olds was significantly different from that for 5-year-olds, $p < .001$, and 6-year-olds, $p = .02$. In addition, the mean score for the 2-year-olds differed from that for the 5-year-olds, $p < .01$.

These results indicate that children younger than 4 years are significantly less likely than children 4 years and older to yawn after being exposed to the yawn of another. In contrast to Anderson and Meno (2003), who observed no contagious yawning prior to age 5, the present study observed contagious yawning as early as 2 years with a significant shift in frequency at 4 years. The differing results between the present data and those of Anderson and Meno (2003) may be the result of presenting the yawning stimuli in a live, implicit paradigm rather than a video, explicit paradigm. Only a single child exhibited contagious yawning at age 2—the age at which Piaget (1951) observed his children to begin yawning contagiously. Given that individuals tend to engage in more mimicry with individuals with whom they have rapport (Chartrand & Bargh, 1999), parents may elicit contagious yawning in their own children earlier than it can be measured by an unfamiliar experimenter. It is also possible that parents may notice a pattern of earlier onset because they have a much larger window in which to observe their children compared with this relatively brief experiment.

The temporal discrepancy between the emergence of spontaneous (rest) yawning and contagious crying (evident from birth), and that of contagious (social-emotional) yawning, indicate that they may not share a common basis. Rather, this later emergence of contagious yawning suggests that it may build upon early empathic or cognitive development.

Study 2

Method

Participants

Participants were 30 children with a diagnosis of an ASD, in addition to 63 TD children. Diagnosis for the ASD group was confirmed by the experimenter (MH) using the Autism Diagnostic Observation Scale (ADOS) using *DSM–IV* criteria (American Psychiatric Association, 1994); see Table 2 for group characteristics. Fifteen children met criteria for autistic disorder on the ADOS, whereas 13 children met criteria for a milder form of autism (PDD-NOS). PDD-NOS refers to cases in which a child experiences marked impairment in social interaction, as well as difficulties with communication and/or stereotyped behaviors patterns or interests but does not meet full diagnostic criteria for autistic disorder. The ethnic background of this group was as follows: One child was African American, 1 child was Asian, and 28 children were Caucasian.

The two TD groups were matched to children with ASD on either chronological age (within 6 months) or mental age (within 6 months) as well as gender. No TD child was used in both mental age (MA) and chronological age (CA) control groups, and none of the children in Study 2 participated in Study 1. The data of 7 TD children were excluded because they were not matched to the ASD group on these parameters. Children with ASD were recruited via flyers at local autism events whereas TD children were recruited via flyers at local family events. In the TD group, 2 children were Asian, 12 children were Latino, 3 children were multiethnic, and 46 children were Caucasian.

Measures

The Socialization domain of the Vineland Scales of Adaptive Behavior–Interview Edition. The Vineland (Sparrow, Balla, & Cicchetti, 1984) is a semistructured parent interview designed to assess a child's adaptive functioning. This study utilized the Socialization domain. Age-equivalent and standard scores for social skills were used in the present analyses.

Autism Diagnostic Observation Scale. The ADOS (Lord et al., 2000) consists of a structured play session that provides participants opportunities to engage in conversation, narrative, problem-solving,

Table 2
Characteristics of Autism Spectrum Disorder (ASD) and Typically Developing (TD) Control Groups in Study 2

	ASD (n = 28)	Mental age-matched TD (n = 28)	Chronological age-matched TD (n = 28)
Chronological age	10:5 (2.2); 6–15 years	9:1 (2.1); 5–13 years	10:3 (2.3); 6–15 years
Mental age (Stanford–Binet)	9:4 (2.0); 5:8–13:4 years	9:2 (2.2); 5:6–13:6 years	12.5 (1.9); 6:2–16:10 years
Vineland (standard) socialization scores			
M	69	101	103
SD	15.87	10.67	11.1
Range	44–100	87–115	92–121
Gender	93% (n = 26) male	93% (n = 26) male	93% (n = 26) male

Note. Results given as mean (standard deviation); range.

and imaginative tasks. The ADOS is scored according to *DSM–IV* criteria for the autism spectrum diagnoses.

Stanford–Binet Intelligence Scale: Fifth Edition (Roid, 2003). In the Stanford–Binet Abbreviated IQ scales, children provide word definitions, yielding a verbal IQ score, and solve a series of picture puzzles, yielding a performance IQ score. This measure provided an index of MA.

Procedure

Children with ASD and TD children sat across the table from a live examiner. Children were tested in a quiet room in their home or in the University of Connecticut Psychological Services Clinic. After an introduction and discussion of the procedure, the experimenter read each child a story, yawning four times during the story. She then administered the Stanford–Binet and (for the ASD group) the ADOS. Because older children, and those who are fluent readers, may have felt uncomfortable with an adult reading to them, those children were told, ''First, I'm going to read you a story, and then I'll ask you some questions about it'' as opposed to simply, ''First, I'm going to read you a story.'' Thus, 14 of the 28 participants in both the ASD and mental-age-matched typically developing control (MA-TD) groups and 22 of the 28 participants in the chronological-age-matched typically developing control (CA-TD) group were told they would be asked questions following the story. In order to explore whether children with ASD yawned spontaneously (as opposed to contagiously) less often than TD children, the test period of the Stanford–Binet administered after the yawning stimuli were also coded for the presence or absence of yawns.

All story sessions were recorded on videotape and coded for looking and yawning behavior by raters blind to group status using the same coding procedures as in Study 1. Interrater reliability, coded for each block, was 83% for looking behavior and 100% for yawning. After the story and test session, parents completed the socialization portion of the Vineland interview.

Results and Discussion

Children with ASD were significantly less likely than TD children to yawn after being exposed to the experimenter's yawn. Only 11% (3/28) of the children with ASD aged 5–12 yawned, compared with 43% (12/28) of a TD control group matched for CA-TD, Fisher's exact $p = .009$, and 36% (10/28) of a control group matched for MA-TD, Fisher's exact $p = .037$ (see Table 3 for group characteristics). When the ASD group was further divided by diagnosis, it became clear that children diagnosed with autistic disorder were less likely to exhibit contagious yawning than children diagnosed with PDD-NOS, $\chi^2(1) = 3.88$, $p = .05$. Specifically, *none* of the children with autistic disorder ($n = 15$) showed contagious yawning, whereas 23% of the children with PDD-NOS ($n = 13$) did. CA, MA, instruction type, visual attention scores, Vineland socialization scores, and diagnosis were entered into a single binary logistic regression model with contagious yawning as a dichotomous variable. In contrast to the results for younger children (ages 1–6 years) found in Study 1, binary logistic regression on contagious yawning in children ages 5–15 years revealed no main effect for age, $p = .80$ (see Figure 1). These data are consistent with the possibility that the rate of contagious yawning remains relatively stable after 5 years, though the relatively small sample size for the current study prevents us from drawing a firm conclusion. No significant effect was found for instruction type ($p = .83$) or MA ($p = .87$). Surprisingly, no significant effect was found for Vineland socialization scores ($p = .924$). The only significant predictor of contagious yawning was diagnosis ($p = .014$), with the absence of an autism spectrum diagnosis increasing the odds of contagious yawning by a factor of 5.8.

A second binary logistic regression was used on the ASD group data only to determine whether autism symptom severity (as indexed by ADOS scores) showed a relation with contagious yawning. Despite the effect of diagnostic severity on yawning contagion, the results suggested no relation between contagious yawning and total ADOS scores, $\chi^2(1, N = 28) = 1.08$, $p = .30$, or communications ($p = .276$) and socialization ($p = .919$) subscales. A possible explanation for this discrepancy is that although the ADOS is an exceptional

Table 3
Number of Children Who Exhibited Contagious Yawning in Study 2 by Group

	Autistic disorder	PDD-NOS	MA-TD	CA-TD
Yawn	0	3	10	12
No yawn	15	10	18	16
% total	0%	23%	36%	43%

Note. PDD-NOS = Pervasive Developmental Disorder, Not Otherwise Specified; MA-TD = mental-age-matched typically developing control; CA-TD = chronological-age-matched typically developing control.

instrument for diagnosing autism, ADOS scores have not been standardized for the purposes of using it as a continuous measure of autism severity. Indeed, individual items on the ADOS vary with respect to their correlation with both IQ and CA (Gotham, Pickles, & Lord, 2009). It is also likely that the very low rate of contagious yawning in the ASD group may have masked relations between contagious yawning and symptom profiles in this group.

Two children with ASD were excluded from analysis because their visual attention scores fell below 12. For the remaining children, ASD (M = 14.6) and TD (M = 15.1) groups did not differ significantly, t = .74, p = .14, on the amount of time spent looking toward the experimenter during the 10 s periods in which the yawning stimuli were presented. As in Study 1, this is likely because the experimenter yawned at times when she was confident that she had the child's attention, not because there are no general differences in visual attention between groups.

Finally, TD children were no more likely to yawn (19.6%) than children with ASD (14.3%) during the nonexperimental portion of the study (such as the Stanford–Binet administration), $\chi^2(1, N = 28) = .091$, $p = .76$. In addition, the experimenter asked the parents of the ASD children whether they believed that their child yawns less frequently than TD children; only one parent responded in the affirmative. Taken together, these data imply that the ASD deficit observed is specific to the contagious, or emotion yawn and does not affect the spontaneous, or rest yawn.

The diminished tendency for participants in the ASD group to yawn contagiously to a live stimulus is consistent with previous findings that individuals with ASD show diminished contagious yawning with a video stimuli (Senju et al., 2007) as well as general deficits in mimicry (McIntosh et al., 2006). The current study is novel in several regards. First, the data demonstrate that individuals with ASD are less likely to yawn contagiously than their TD peers, even when controlling for MA and gender. Second, the magnitude of this difference in autistic disorder is much greater than previously reported, when using live rather than videotaped stimuli. Most importantly, the current data demonstrated a striking effect of diagnosis, with children with autistic disorder being less likely to show contagious yawning than children with PDD-NOS. Autistic disorder is characterized by more marked deficits in the realms of communication, social relatedness, and stereotyped interests and behaviors. Thus, the latter findings indicate a significant relation between diagnostic severity in ASD, and susceptibility to contagious yawning.

At a broad level, the late onset of this phenomenon in typical development implies that an autistic deficit in contagious yawning may be a reflection of a deficit in early social learning that affects the ability or tendency to mimic the actions and emotions of others. Nonemotional sounds and mouth movements, such as mouth opening when feeding a baby, are unintentionally imitated (Heyes, 2001) and modulated by experience (Heyes, 2005). Future research is needed to explore whether these forms of mimicry are unconsciously imitated by children with autism (work that is currently underway in this lab). If they are not, this finding would lend further support to the proposal that there is an autistic deficit in recognizing or acting on the correspondence between oneself and others (an ability that all mimetic and imitative acts depend upon). Alternatively, individuals with autism may demonstrate a specific deficit in mimicking emotional behavior. Indeed, emotion perception is a documented area of weakness for individuals with autism (e.g., Moody, McIntosh, Mann, & Weisser, 2007).

General Discussion

The present study demonstrates that children younger than 4 years are significantly less likely to yawn contagiously when exposed to a live stimulus—that is, after seeing another, nearby person yawn—than children ages 4 years and older. The very early emergence of *spontaneous* yawning (by the end of first trimester of pregnancy) offers an informative contrast to the much later, postnatal development of *contagious* yawning. This developmental lag may reflect the phylogenetic antiquity of the motor act of yawning (demonstrated in most vertebrates) relative to the recent evolution of contagion (convincingly demonstrated only in humans and chimpanzees; Anderson, Myowa-Yamakoshi, & Matsuzawa, 2004). The present study also demonstrates that children with ASD are significantly less likely to yawn contagiously when exposed to a live stimulus than TD children. Furthermore, those with a diagnosis indicative of more severe autistic symptoms (autistic disorder) are significantly less likely to yawn contagiously than those with a diagnosis indicative of milder autistic symptoms (PDD-NOS). Taken together, these studies provide further validation for the distinction between spontaneous (or ''rest'') yawns and contagious (or ''emotion'') yawns, and suggest that contagious yawning is linked with social development.

More research is needed to establish whether contagious yawning is unique or whether all forms of mimicry increase over the course of typical development (potentially with a substantial shift in competence occurring around the age of 4). However, one potential implication of the late onset of contagious yawning in typical development and its near absence among individuals with ASD is that mimicry, and hence emotional contagion, may increase with social experience. It is fairly easy to imagine how mimicry may come to substantially increase during the first years of life. First, it is adaptive for an individual to learn to ''automatically'' experience the emotions displayed on the faces of conspecifics (i.e., experience those emotions without deliberation or analysis). For example, if an individual becomes afraid and retreats upon seeing a predator, it is adaptive for an individual to retreat rather than analyze the situation. Likewise, automatically experiencing a conspecific's disgust may protect an individual from ingesting the same harmful food item (Goldman, 2005).

In the case of yawning, experiencing fatigue along with conspecifics may have served the primary evolutionary function of synchronizing a social group's biological rhythms (Schurmann et al., 2004). Indeed, there is some evidence that social cues alone may sustain shared circadian rhythms in the absence of light (Aschoff et al., 1971). Alternatively, rather than serving a direct evolutionary purpose, contagious yawning may have arisen as a by-product of the automatic tendency to facially mimic others (adaptive in rapidly spreading signals of risk and reward throughout a group).

In addition to facilitating emotional and biological synchronization, mimicry may serve to increase feelings of closeness and connection between individuals (Lakin, Jefferis, Cheng, & Chartrand, 2003). These feelings of affiliation, in turn, increase the amount of mimicry individuals display toward one another (Lakin et al., 2003). This process may escalate in a continuous cycle first between child and parent and, later, child and other members of the community, during the early years of development. Out of such increasingly synchronous bonds may develop abilities such as speech (i.e., Bruner's ''proto-conversations''; Bruner, 1983), joint attention, and deliberate imitation.

It is possible that infants with autism are not able to perceive that they are being mimicked (due to reduced social attention or difficulties with emotion perception) or are unable to mimic accurately (due to difficulties in motor function or self-other mapping), and so synchronization with mother and other members of the social group is less available throughout development. This lack of early mimicry could also affect feelings of psychological connection and opportunities for social learning. These changes could thus leave children with autism unable to recognize primitive socioemotional cues that could otherwise serve to biologically and emotionally synchronize them with people around them.

Speculation About Underlying Neural Mechanisms

Brain imaging studies may hold some promise for shedding light on the neurological substrate of contagious yawning. Two neuroimaging studies have explored contagious yawning by exposing participants to videos of others yawning. One study (Platek, Mohamed, & Gallup, 2005) showed increased activation in the precuneus and posterior cingulate gyrus when participants viewed videos of yawning relative to videos of laughter (another emotionally contagious stimulus). The authors interpreted this activation as evidence that contagious yawning, compared with laughter, involves nonconscious aspects of self-referencing. A second study (Schurmann et al., 2004) found that watching yawn videos elicited activation in a region associated with perception of biological movement—particularly perception of eye and mouth movements (the superior temporal sulcus). In addition, they reported that self-reported desire to yawn was negatively correlated with periamygdalar activation (a region implicated in arousal)—a finding that likely derives from the negative relation between arousal and yawning. Neither study found any special involvement of the *mirror neuron system* (MNS)—a system that is active both when one observes and executes an action—for yawning over and above that recruited for the control stimuli (laughing or neutral faces, and meaningless mouth movements, respectively). An obvious limitation of these studies is that the participants in these studies did not ''catch'' the yawns; they simply reported upon their desire to yawn while viewing the yawning stimuli and thus did not actually experience any form of emotional contagion.

Studies investigating forms of empathy and emotional convergence that more readily lend themselves to neuroimaging have consistently found activation in the insula and anterior cingulate cortex (ACC). We speculate that these areas are likely candidates for distinguishing the neural activation associated with contagious yawning over and above that associated with any type of action (and thus the MNS) including spontaneous yawning or other mouth movements, that is, the regions we speculate underlie the *contagious* component of yawning. Just as the ''MNS'' may underlie common coding of actions, studies have demonstrated the same common coding in the insula and ACC between first- and third-person experiences of emotional information, such as disgust (Wicker et al., 2003), pain (Singer et al., 2004), emotional body language (de Gelder & Hadjikhani, 2006), and emotional expressions (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003). A recent study of children ages 9–10 years supports the involvement of the insula, as well as inferior frontal mirror areas and the amygdala, in the observation and imitation of emotional expressions (Pfeifer, Iacoboni, Mazziotta, & Dapretto, 2008). Furthermore, activation in these areas was associated with the children's empathy levels. In children with autism, activity in these same areas during the observation of emotional expressions has been found to be negatively correlated with symptom severity (Dapretto et al., 2006).

One type of neuron unique to the insula and the ACC is the spindle cell, also known as the Von Economo neuron (VEN). Spindle cells are a late-evolving class of neurons that allow for the conscious monitoring of visceral signals from the body, a process that may underlie the impact of afferent feedback. These neurons do not achieve their ultimate postnatal number until the age of 4 years (the age at which we demonstrate the robust emergence of contagious yawning) and have been reported to be disordered in autism (Allman, Watson, Tetrault, & Hakeem, 2005). VENs are responsible for rapidly extracting statistical probabilities from sensory input based on previous information, giving rise to nonconscious emotional reactions. The more experience we gain, the more we may be able to recognize such patterns and associations, and the more developed these neurons may become. The diminished tendency for contagious yawning in children with ASD could be the result of primary or secondary neurological differences affecting these neurons.

Limitations

While study results were fairly unambiguous, findings are necessarily limited in several dimensions. First, although looking time, or general attention to the experimenter, was accounted for in the present studies, we could not unequivocally verify whether participants were attending to the eye or the mouth region of the speaker; this would have required additional eye tracking methods. This limitation is relevant because Provine (1989) has found that yawning contagion, when elicited by pictures of others yawning, is dependent upon attending to the region of the eyes rather than the mouth. Eye tracking studies have revealed that individuals with autism preferentially fixate on the mouth rather than the eye regions (Klin, Jones, Schultz, Volkmar, & Cohen, 2002), leaving open the possibility that a lack of attention to the *eye region* of others' faces (rather then a deficit in unintentional mimicry) is responsible for diminished yawning contagion in this group. Similarly, as typical children age, they may pay closer attention to the faces of others, resulting in more facial mimicry, and hence, greater emotional and biological attunement with those around them. In contrast, children with autism may never learn to pay closer attention to the faces of those around them, and so their tendency to mimic others, as well as their emotional attunement with others, may not increase over time in the way one observes in typical development. If so, this lack of attention to faces may have a previously unsuspected significance in that it may serve to impair mimicry, resulting in decreased emotional resonance, and perhaps even decreased biological synchrony with others.

An argument against this explanation of the findings is that yawning, like crying and laughing, is a contagious act that produces a sound, and the sound alone is often sufficient to trigger its contagion (Provine, 1996). Indeed, the experimenter in this study produced yawns that included the prototypical auditory accompaniment of an indrawn breath followed by a voiced sigh. In addition, given that there were no significant differences in visual attention to the yawns between the 4-year-olds (the age at which a major susceptibility shift was observed) and the other age groups, the developmental results seem unlikely to be due merely to age-related shifts in visual attention.

Finally, although the low rate of contagious yawning in the ASD group speaks to its significance, it made it impossible to determine the extent to which contagious yawning in this population, when it does occur, is correlated with specific autistic symptoms. If more children with ASD could be found who do yawn contagiously, it might be possible to determine whether such factors correlate with contagious yawning in autism, shedding increased light on the implications of this deficit.

Summary and Conclusions

In order to elucidate the developmental properties of automatic facial mimicry in the form of contagious yawning, we investigated the extent to which groups of children at various stages of social development (TD children ages 1–6, as well as children with ASD) are susceptible to contagious yawning. Findings strongly suggested that children under the age of 4 and children with ASD are less likely to yawn when exposed to another's yawn. The developmental curve associated with the onset of contagious yawning implies that emotional contagion becomes more developed and more sensitive over time, resulting in increased affective attunement with others as children grow older. Meanwhile, individuals with ASD may not experience increased emotional contagion during the early years of development, causing them to be deficient in the automatic emotional reciprocity that psychologically binds most individuals together. More research is necessary to determine what mediates this phenomenon; however, it is possible that in the future contagious yawning may prove to provide a simple measure of automatic facial mimicry, empathy, or perhaps even a biomarker of clinically important neurological characteristics that does not require specialized equipment or testing to detect.

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