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Increased Contagious Itch in Children with Autism Spectrum Disorder (ASD)

Molly Schineller
Trinity College, Hartford Connecticut

Trinity College
HARTFORD CONNECTICUT

TRINITY COLLEGE

INCREASED CONTAGIOUS ITCH IN CHILDREN

WITH AUTISM SPECTRUM DISORDER (ASD)

BY

Molly Schineller

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Molly Schineller

Honors Thesis Committee

Approved:

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Molly Helt, Thesis Advisor

_____

Sarah Raskin, Thesis Committee

_____

Sarah Raskin, Director, Neuroscience Program

Date: _____

Abstract

It has been previously demonstrated that contagion of yawning and laughter is significantly reduced in individuals with Autism Spectrum Disorder (ASD) in comparison to age-matched typically developing (TD) children, but contagion of itch has not been studied in this population. In this study, 55 children with ASD and 55 TD children, all aged 9-14, were exposed to video clips depicting actors yawning, laughing, and itching. In line with previous data, children with ASD demonstrated decreased contagious yawning and laughter in comparison to their TD peers. Surprisingly, they demonstrated increased contagious itch compared to their TD peers. However, susceptibility to contagion of itch and autism severity as measured by total ADOS score were unrelated. In addition, the location of the stimulus itch had no impact on the susceptibility to contagious itch in either group. Potential implications on mirror neuron theory as it pertains to ASD and the origin of mimicry deficits in ASD are explored.

Introduction

Contagion, a term typically used in the medical field to describe the spread of viruses and

infections, can also be used to describe the transmission of social behaviors such as yawning,

laughing, and itching. The process of contagion begins with the inherently social observation of

another individual performing a particular behavior. This passive observation then translates into

action, at which point the observer may unconsciously mimic the behavior they have observed.

This mimicry is influenced by various factors, such as social affiliation between the individual

and the target (Dissanayake & Crossley, 1996), and personality traits of the individual, such as

empathy (Sorensen, 2017) . In the general population, seeing, reading, or even simply thinking

about yawning behaviors in others induces a yawn in the observer about 55% of the time

(Provine, 2005b). Seeing or imagining others laughing can similarly cause an individual to

perform that behavior in the majority of cases (Provine, 2005a). Autism Spectrum Disorder

(ASD) is a developmental disorder characterized by social communication deficits, repetitive

behavior, restricted interests (American Psychiatric Association, 1994), and reduced facial

observation (Dalton et al., 2005). Individuals with ASD tend to demonstrate socially contagious

behaviors to a lesser degree than their typically developing (TD) counterparts (Hermans, van

Wingen, Bos, Putman, & van Honk, 2009; Helt, Eigsti, Snyder, & Fein, 2010; Helt & Fein,

2016).

Itching follows a similar structure of transmission to yawning and laughter, whereas

observing another individual scratching can cause the observer to instinctively scratch as well

(Holle, Warne, Seth, Critchley, & Ward, 2012). Though yawning and laughter center solely on

facial activity, itching can vary in location across the entire body. Thus, while the contagion of

yawning and laughter relies on information transmitted via observation of the face, itch

contagion may be transmitted without direct facial visualization. This factor could potentially

cause itch contagion to present differently than yawn or laugh contagion in individuals with ASD

because this population typically demonstrates reduced facial observation.

Decreased mimicry in ASD

Mimicry is defined as matched behavior generated through unconscious repetition of

another person's actions (Want & Harris, 2002). Prior studies in this field have demonstrated that

behaviors involving mimicry—including contagion of emotionally-linked processes such as

facial expression, yawning, and laughing—are reduced in individuals with ASD (Hermans et al.,

2009; Helt et al., 2010; Helt & Fein, 2016). In a study regarding contagion of yawning behaviors,

children with ASD were significantly less likely to repeat a stimulus yawn they had observed

than TD children were; 11% of the children with ASD and 43% of the TD children demonstrated

contagion of the yawn stimulus (Helt et al., 2010). The results of another study on contagion of

laughing showed a significant relationship between low matched affect change in response to

hearing a laugh track and high ASD severity, as measured by the ADOS assessment (Helt &

Fein, 2016). A separate study demonstrated reduced mimicry of facial expression in females with

autistic traits as opposed to TD participants by using fEMG to record their facial muscle activity

in response to photos depicting angry and happy expressions (Hermans et al., 2009). The

common theme throughout these studies is that individuals with ASD demonstrate an reduction

in behaviors that require mimicry. To this point, the relationship between ASD severity and

contagion of itch has not yet been explored.

Contagious itch in TD populations

While contagious itch has not been previously studied in populations with ASD, it has been comprehensively explored in TD individuals. Most studies of this nature compare healthy individuals with those managing preexisting skin conditions, such as atopic dermatitis, which is a consistent, itchy inflammation of the skin. Papoiu, Wang, Coghill, Chan, and Yosipovitch (2011) demonstrated that individuals who have atopic dermatitis scratch more frequently when exposed to video clips depicting actors scratching themselves, than when exposed to neutral video clips which do not depict itching behaviors. Expanding this research to include healthy individuals without skin disorders, Schut, Grossman, Gieler, Kupfer, and Yosipovitch (2015) demonstrated that both individuals with atopic dermatitis and healthy individuals experience contagious itch when exposed to videographic itch cues, but those with the preexisting condition are more likely to scratch than their healthy counterparts. Additional studies have demonstrated that even photographic stimuli, as opposed to the aforementioned videographic stimuli, can induce contagious itch in both individuals with existing skin conditions and healthy individuals (Lloyd, Hall, Hall, & McGlone, 2012).

Neural mechanisms of itch

Although contagious itch is the primary focus of this study, it is also worthwhile to define its instinctive counterpart, spontaneous itch, which is triggered in response to uncomfortable physical and chemical stimuli directly on or under the skin. Contagious itch, in contrast, is defined as a mirroring response not prompted by physical or chemical stimuli, which is transmitted by observing the behavior or envisioning itch-inducing circumstances (Papoiu et al., 2011).

Regardless of whether an individual exhibits spontaneous or contagious itch, the same corresponding "itch matrix" of neural regions has been demonstrated to commonly activate, as evidenced through fMRI studies (Holle et al., 2012; Paus, Schmelz, Biró, & Steinhoff, 2006). The implicated brain regions—including the somatosensory cortex, thalamus, insula, anterior cingulate cortex, prefrontal cortex, and primary motor cortex—each possess functions that clearly illustrate their relevance to the process of itching (Holle et al., 2012). The somatosensory cortex, for instance, receives sensory input such as physical or chemical stimuli, which would include scratching stimuli in the case of spontaneous itch. The thalamus, which is responsible for sensory perception and regulation of movement, is directly involved in perceiving physical, chemical, or observational itch stimuli and directing the individual with the intention to scratch. The insula, which is known to be implicated in personal processes such as cravings and self-awareness (Mochizuki, Papoiu, & Yosipovitch, 2014), is deeply intertwined with the subjective affective experience of itch transmission in which external sensory stimuli are paired with the individual's internal state (Holle et al., 2012; Uddin & Menon, 2009). The anterior cingulate cortex connects the aforementioned limbic brain regions to the prefrontal cortex, thus linking the emotionally oriented system of the brain to the cognitive-focused areas. The prefrontal cortex is critical in the brain's pleasure and reward system, aversiveness, and decision-making—which in the case of itch would refer to processes such as deciding whether to itch or not to itch. Finally, after transmission of the stimulus through all the prior brain regions in the itch matrix, the primary motor cortex is ultimately responsible for generating the physical motions of the itch.

Differences in brain structure and personal traits in ASD

The insula is an especially relevant brain region to consider in research on ASD, because the phylogenetically recent network of spindle neurons contained within this structure is particularly underdeveloped in children with ASD in comparison to TD children, who typically are fully developed in this area by approximately age four (Uddin & Menon, 2009). Also of particular relevance in research on itch response is the preferential distribution of itch matrix activation in brain regions in left hemisphere as opposed to the right (Greaves, 2007).

The left half of the prefrontal cortex, in addition to being preferentially active in itch responses, is also known to demonstrate higher activation in individuals who express higher levels of neuroticism—the tendency to experience negative emotion (Holle et al., 2012). Individuals with ASD exhibit neuroticism at higher levels than TD individuals (Fortenberry, Grist, & McCord, 2011). Past studies have demonstrated that the degree of contagion of an itch stimulus may be related to trait differences in neuroticism across individuals, which would thus regionally link the itch matrix with neurotic intrapersonal traits (Holle et al., 2012). Empathetic intrapersonal traits have also previously been hypothesized to possess a link to degree of itch contagion, but evidence toward this hypothesis have been inconclusive: some studies conclude that the two are not connected (Holle et al., 2012), while still other studies support the relation between empathy and itch contagion (Schut et al., 2015).

Mirror neurons and ASD

It has been hypothesized that contagious behaviors may be functionally linked to density of mirror neurons, which demonstrate the same firing activity whether an action is observed or enacted (Williams, Whiten, & Singh, 2004). Individuals with ASD typically possess a lower

density of mirror neurons (Oberman et al., 2005) and decreased activation in common mirror

neuron regions (Dapretto et al., 2006) as compared to TD individuals, and perhaps relatedly,

individuals with ASD also demonstrate a reduction in social behaviors that include the mimicry

necessary for contagion of itch. However, there is debate as to whether mirror neurons form an

innate link between ourselves and others, which are primarily genetically disrupted in individuals

with ASD resulting in reduced social attention and mimicry *or* whether "mirror neurons" are

simply networks of neurons which exhibit mirroring properties as the result of associative social

learning, and it is this reduced social attention which is primary in ASD, which then results in

reduced density of neurons with mirroring capabilities. The distinction between mirror neurons

and neurons with mirroring properties is currently debated across multiple fields; for the sake of

clarity, we will refer to these neurons as mirror neurons in the remainder of this paper.

The discrepancy in mirror neuron density seen across individuals with ASD and

age-matched TD counterparts could hypothetically explain the characteristic differences in social

behavior if mirror neuron formation occurs automatically during early development. Having

fewer neurons to stimulate the mimicry deeply involved in social behavior would logically

reduce the frequency of social interaction itself. Current literature on mirror neuron origins,

however, has not conclusively determined whether mirror neurons are naturally developed upon

birth, or if they are developed over time through associative learning in response to social

interactions. If mirror neurons are formed based on associative learning rather than formed

automatically during development, perhaps the reduction of social behavior seen in ASD could,

inversely, be a cause of the reduced mirror neuron density. Should mirror neurons develop based

on associative learning, early therapeutic intervention in ASD could potentially mitigate the

reduced mirror neuron density characteristic of the disorder by successfully increasing the

interactions necessary for their formation.

Current study and hypotheses

Contagion of yawning and laughter have already been shown to be reduced in children

with ASD (Helt et al., 2010; Helt & Fein, 2016). Prior to the study at hand, however, it has not

been determined whether contagion of itch also deviates from the norm in this population. If

contagion overall is based on one set of abilities an individual must possess, then it would be

expected that contagious itch will be decreased, just as yawning and laughing are, in children

with ASD. Susceptibility for contagion of different stimuli, however, may be enhanced through

varied developmental timelines and social learning experiences. A possible example of varied

timelines for contagious behaviors is that individuals with ASD typically demonstrate reduced

eye gaze and face processing (Dalton et al., 2005); this could mean that contagion of behaviors

requiring visualization of the face can only occur in individuals who have learned to fixate upon

the face and unconsciously mimic behaviors transmitted via this region. The reduction in

contagion of yawning and laughter in children with ASD, therefore, may exist because this

population usually follows a slower developmental timeline for this particular type of contagious

stimuli.

If mirror neurons develop due to associative learning, it would be expected that only

mirroring of behaviors that occur in the facial region would be impaired in individuals with

ASD. Thus, as itch stimuli can occur in any location on the body—not necessarily focused in the

facial region—we hypothesize that children with ASD will demonstrate similar levels of itch

contagion to TD children matched for mental age (*Hypothesis A*). If the results support this

hypothesis, we will have demonstrated that mirroring as a whole is intact in children with ASD, and that the decreased contagion of other behaviors in individuals with ASD (Helt et al., 2010; Helt & Fein, 2016) is likely due to decreased facial visualization rather than due to innate mirroring deficits in ASD. Further, we hypothesize that, in children with ASD, itch stimuli located further from the face will induce a high frequency of contagion as compared to itch stimuli located on the face or head, due to the reduced facial visualization expected in these participants (*Hypothesis B)*.

Methods

Participants

Initially, 121 participants were recruited for this study. Of those recruited, 63 children were recruited for the TD group and 58 children were recruited for the ASD group.

Participants with ASD were recruited through flyers sent home with children at schools and programs for children with ASD or sent by mail and email directly to families who had previously stated interest in autism research at Trinity College, through emails to organizations supporting individuals with autism (CT FEAT, Autism Speaks CT, CPAC CT), and through sign-up tables at local autism-themed events (Hartford Autism Speaks walk, Autism Day at Lake Compounce, CT Special Olympics). TD participants were recruited through flyers sent home with children at an elementary school and a middle school and via word of mouth from participants with ASD.

Exclusion criteria for children with ASD included failure to score within the ASD range on the Autism Diagnostic Observation Schedule (Lord et al., 2000) or diagnosis with additional disorders known to alter cognitive functioning, including fragile X syndrome, Down syndrome, and epilepsy. In addition, any participants who did not match a participant in the other group for gender and/or chronological age within six months, estimated based on scores on the Stanford-Binet Intelligence Scales (Roid, 2003), were excluded. Based on these criteria, three children from the ASD group were excluded due to ADOS scores below the threshold to confirm diagnosis with ASD, and eight children from the TD group were excluded because their genders or chronological ages did not match those of the participants in the ASD group within six months.

Thus, the participants for the study ultimately consisted of an ASD group of 55 children aged 9-14 (11.0 ± 1.8), and a TD group of 55 children aged 9-14 (11.5 ± 1.5). Ethnicities of all participants are reported in *Table 1*. All other demographic data, including chronological age, mental age, ADOS scores, and self-reported gender are reported in *Table 2*.

Table 1. Self-reported ethnicities for participants in ASD and TD groups.

Group	Mixed race	Asian	African-American	Hispanic	Caucasian	Unreported
ASD (n = 55)	3	2	1	0	46	3
TD (n = 55)	5	5	1	5	39	0

Table 2. Demographic data for participants in ASD and TD groups: chronological age, mental age, ADOS scores, and self-reported genders for participants in ASD and TD groups. Reported as mean ± standard deviation, range. Independent samples t-tests demonstrated that ASD and TD groups were statistically similar in chronological age, $t(54) = 1.477$, $p = 0.145$, but different in mental age, $t(54) = 5.432$, $p < 0.001$.

Group	Chronological age (years)	Mental age (Stanford-Binet)	ADOS	Gender (male : female)
ASD (n = 55)	11.0 ± 1.8, 9-14	9.7 ± 1.8, 5.2-13.8	14.4 ± 2.2, 12-18	49 : 6
TD (n = 55)	11.5 ± 1.5, 9-14	11.4 ± 1.7, 8.1-14.4	N/A	50 : 5

Materials

Autism Diagnostic Observation Schedule, or *ADOS* (Lord et al., 2000):

The ADOS consists of a semi-structured assessment of social, communicative, play, and imaginative behavior. Participants in the ASD group were given Module 3 of the ADOS, which

is intended to test verbally fluent children for ASD-characteristic symptomatology. Scores on this test were evaluated using DSM-IV criteria, which specify that scores higher than 12 qualify for diagnosis with ASD (Lord et al., 2000; American Psychiatric Association, 1994).

Stanford-Binet Intelligence Scales, Fifth Edition (Roid, 2003):

The Stanford-Binet creates a composite IQ score for each participant based on performance in word definition and picture puzzle tasks. Scores from this test served as an index of mental age for each participant, which was used to pair participants in the ASD and TD groups according to mental rather than chronological age. This step was crucial, as mental age frequently differs from chronological age in populations with ASD (Baron-Cohen, Leslie, & Frith, 1985).

Short Sensory Profile, or SSP (McIntosh, Miller, & Shyu, 1999):

The SSP is a measure of sensory processing typically used to evaluate children with ASD. This test consists of 7 sections, including tactile sensitivity, taste/smell sensitivity, movement sensitivity, under-responsive seeking sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity (Tomchek & Dunn, 2007). Scores from this test will inform further analysis on sensory hypersensitivity in this population.

Multidimensional Emotional Empathy Scale, or MDEES (Mayer, Caruso, & Salovey, 1999):

The MDEES consists of 30 statements, which participants were asked to agree or disagree with using a 5 point Likert scale. Scores from this test provided information about the degree to which each participant's feelings are affected by the feelings and situations of those around them, and will be further analyzed in future publications regarding this cohort.

Procedure

Assessments:

The experiment was conducted individually with each participant. The testing location was a quiet room in the participant's home. The procedure was discussed with participants and caregivers immediately prior to assessment, then caregivers were offered informed consent and participants with a reading level corresponding to chronological age eight were offered assent. Following this step, the Stanford-Binet was administered to all participants. The ADOS was then administered only to participants reporting diagnoses of ASD. In addition to these tests, participants were evaluated using the SSP and the MDEES, the data of which will be reported in a separate publication.

Video clip stimuli:

Participants were shown 60 thirty-second video clips: 20 demonstrating a yawn stimulus, 20 demonstrating a laugh stimulus, and 20 demonstrating an itch stimulus. Order of administration of the video clips was randomly chosen. All video clips were created in our lab and featured actors of various ages, including adults, children, and babies. Itch video clips depicted scratching in one of four location categories: face, head, arm, and hand. The variability of categorical itch locations allowed testing of the hypothesis related to distance from the face. Toward this hypothesis, head and face stimuli were included as stimuli 'close to the face,' and arm and hand stimuli were included as stimuli 'distant from the face.'

Coding criteria:

Responses of participants were videotaped and then coded for several different components: a) attention to the video clip, b) occurrence of yawning, laughing, or itching, c)

whether the response type matched the stimulus type, and d) location of itch responses. Recordings that were coded affirmative for a response behavior demonstrated a participant response within ten seconds of the end of the stimulus behavior seen in the video clip. Yawns were counted if participants demonstrated the hallmark physical components of yawning, including open mouth, inward breath, and short exhalation (Provine, 2005b). Laughs were counted if participants demonstrated an upward shift of the corners of the mouth, accompanied by vocal sounds, vibration of throat and shoulders, or rapid exhalation of breath (Kawakami et al., 2006). Itches were counted if the participant scratched an area of the body with their nails or fingertips.

Itch response locations were classified in the same four categories as itch stimulus locations: head, face, arm, or hand. The head category included responses on the back and front of the neck, chin, ears, and areas covered by the hair. The face category included any area on the front of the head such as nose, forehead, eyebrows, eyes, mouth, and temples. The arm category included upper and lower arm regions. The hand category included the fingers and the tops and palms of the hands.

Inter-rater reliability:

Inter-rater reliability across our two raters was 100% for recorded responses coded for yawning, 92% for recorded responses coded for laughing, and 97% for recorded responses coded for itching.

Statistical analysis:

In order to investigate the two hypotheses, the data on itch responses were classified binarily in two different categories: a) diagnosis with ASD vs. no diagnosis, b) stimulus itch

close to the face vs. distant from the face. Coded results were later statistically analyzed using

SPSS (IBM, 2013).

Results

In order to verify that the sample population demonstrated the impairments in mimicry typical of individuals with ASD, yawning and laughing data were analyzed first. The data did indeed depict significantly fewer contagious yawns in children with ASD (0.35 ± 0.48) than in TD children (0.70 ± 0.66), $t(54) = 3.53$, $p < 0.001$, and significantly fewer contagious laughs in children with ASD (1.33 ± 1.16) than in TD children (3.41 ± 1.85), $t(54) = 7.71$, $p < 0.001$, based on two independent samples t-tests presented graphically in *Figure 2*. These results show that the populations of children with ASD and TD children who participated in our study demonstrate the typical, expected levels of mimicry seen in preliminary studies. Thus, it was determined that results based on the itch data could also be considered reasonably representative of the differences between individuals with ASD and TD individuals.

Prior to evaluating the hypotheses, it was also important to verify that the participants with ASD did not demonstrate a significantly higher level of baseline itching than their TD counterparts. Spontaneous itches during video clips depicting yawning and laughing, which should not invoke an itch response, were quantified and analyzed using independent samples t-tests. These analyses ultimately demonstrated that the ASD and TD groups have similar levels of baseline itching (*Figure 1*), based on the statistically insignificant differences between the two groups during yawn stimuli, $t(54) = 0.44$, $p = 0.66$, and during itch stimuli, $t(54) = 1.73$, $p = 0.09$.
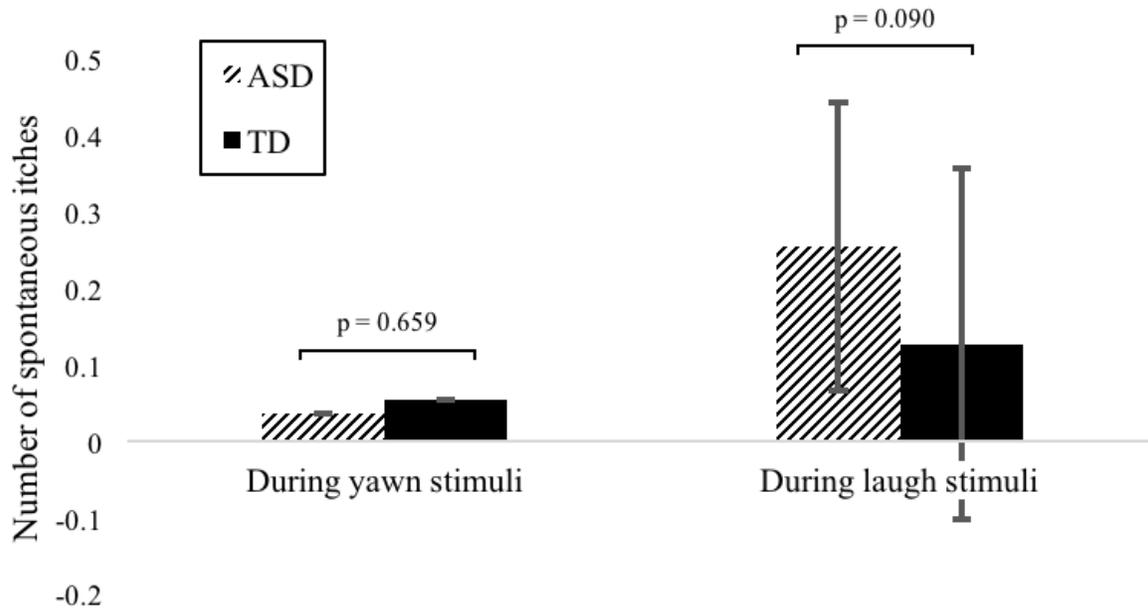
Figure 1. Mean numbers of spontaneous itches during video clips depicting yawning and laughing, across

both testing groups (ASD and TD), depicted graphically with error bars. *ASD*: during yawn stimuli (0.04

± 0.19), during laugh stimuli (0.25 ± 0.44). *TD*: during yawn stimuli (0.05 ± 0.23), during laugh stimuli

(0.13 ± 0.34). Spontaneous itches during both yawn and laugh stimuli, respectively, demonstrated

statistically similar baseline itching levels across the ASD and TD groups, based on independent samples

t-tests: *yawn: t*(54) = , *p* = 0.659; *laugh: t*(54) = , *p* = 0.090.

Data were then analyzed to evaluate the validity of three hypotheses:

Hypothesis A: We hypothesized that contagion of itch stimuli would be unchanged or decreased

in children with ASD in comparison to TD children, based on preliminary studies which

demonstrated reduced contagion of yawning (Helt et al., 2010) and laughter (Helt, Fein, &

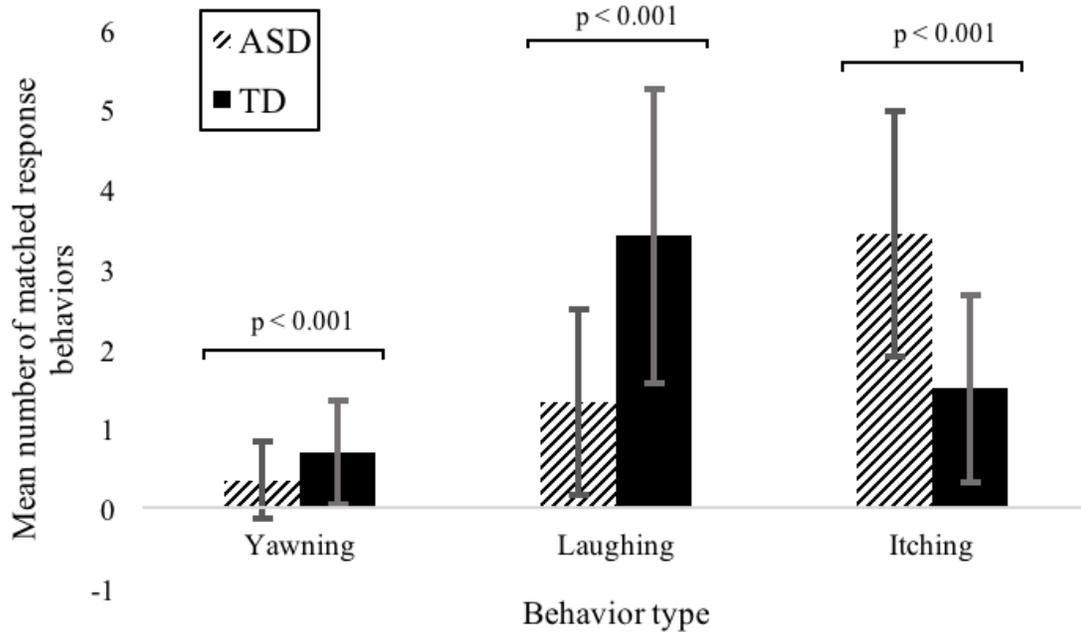Vargas, submitted) in children with ASD.

Figure 2. Mean numbers of response behaviors (yawns, laughs, and itches) across both testing groups

(ASD and TD), depicted graphically with error bars. *ASD*: yawn (0.35 ± 0.48), laugh (1.33 ± 1.16), itch

(3.4 ± 1.5). *TD*: yawn (0.70 ± 0.66), laugh (3.41 ± 1.85), itch (1.5 ± 1.1). All three behaviors

demonstrated statistically significant difference between ASD and TD groups based on independent

samples t-tests: *yawn*: $t(54) = 3.53$, $p < 0.001$; *laugh:* $t(54) = 7.71$, $p < 0.001$; *itch:* $t(54) = 7.88$, $p < 0.001$.

An independent samples t-test showed that contagion of itch stimuli was significantly

higher in participants with ASD (3.4 ± 1.5) than in TD participants (1.5 ± 1.1), $t(54) = 7.88$, $p <$

0.001 (*Figure 2*). These results countered our expectation, as we had predicted we would see

reduced contagion of itch in children with ASD. It was expected that transmission of itch

contagion would behave similarly to contagion of yawn and laugh.

Hypothesis B: Of the trials in which itches were contagious, some stimulus video clips depicted

scratches close to the face (on the head or face), and some depicted scratches distant from the

face (on the arm or hand). We hypothesized that children with ASD would demonstrate a

significantly lesser proportion of response itches to stimuli located close to the face than TD

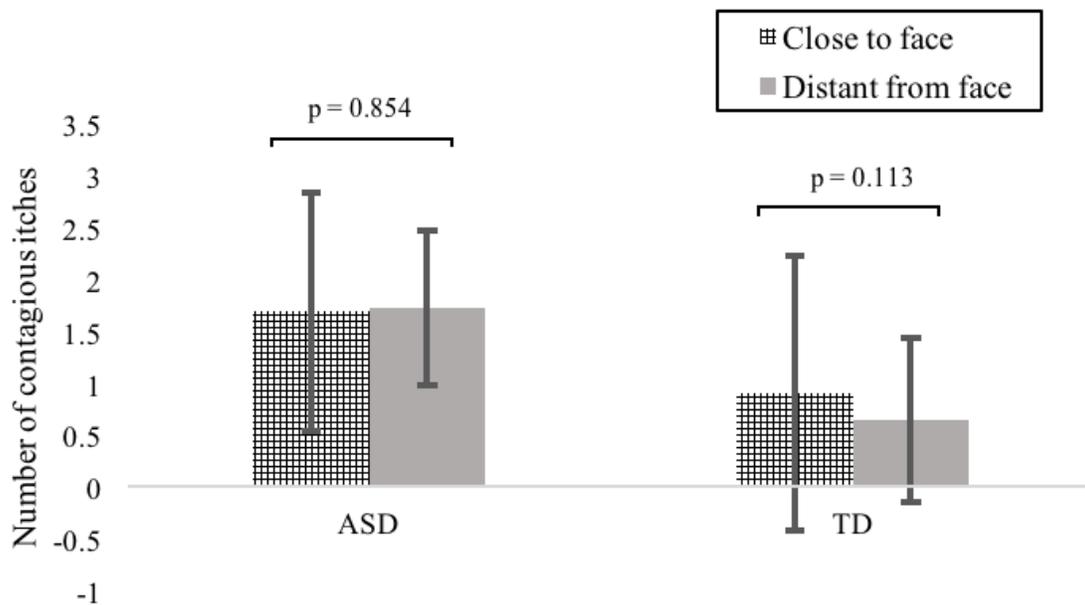children due to the reduced facial visualization characteristic of ASD.

Figure 3. Mean numbers of itches across both participant groups (ASD and TD), across the two stimulus

location categories: close to face (head and face stimuli) and distant from face (arm and hand stimuli),

depicted graphically with error bars. *ASD*: close (1.7 ± 1.2), distant (1.7 ± 1.3). *TD*: close (0.9 ± 0.7),

distant (0.6 ± 0.8). Neither the ASD group nor the TD group showed a statistically significant difference

in number of contagious itches across the two location groups, based on independent samples t-tests:

ASD: t(54) = 0.173, *p* = 0.854; *TD: t*(54) = 1.613, *p* = 0.113.

The ASD group demonstrated almost the same number of itches in response to stimuli

close to the face (1.7 ± 1.2) as to those distant from the face (1.7 ± 1.3). The TD group showed a

slight discrepancy between the two stimulus itch location categories, with more itches close to

the face (0.9 ± 0.7) than distant from the face (0.6 ± 0.8). Results of the independent samples

t-test run on facial distance data did not show a significant difference in proportion of contagions

located close to the face versus distant from the face in children with ASD, $t(54) = 0.173$, $p =$

0.854, nor in TD children $t(54) = 1.613$, $p = 0.113$ (*Figure 3*). In other words, distance from the

face did not have the expected impact on contagiousness of itch stimuli in children with ASD.

Hypothesis C (post-hoc): Following the unexpected increase of itch contagion in children with

ASD seen above, it was further speculated that children with a more severe ASD diagnosis

would show a more exaggerated increase in itch contagion, due to the fact that they are more

cognitively different from TD children. Specifically, it was hypothesized that ADOS score would

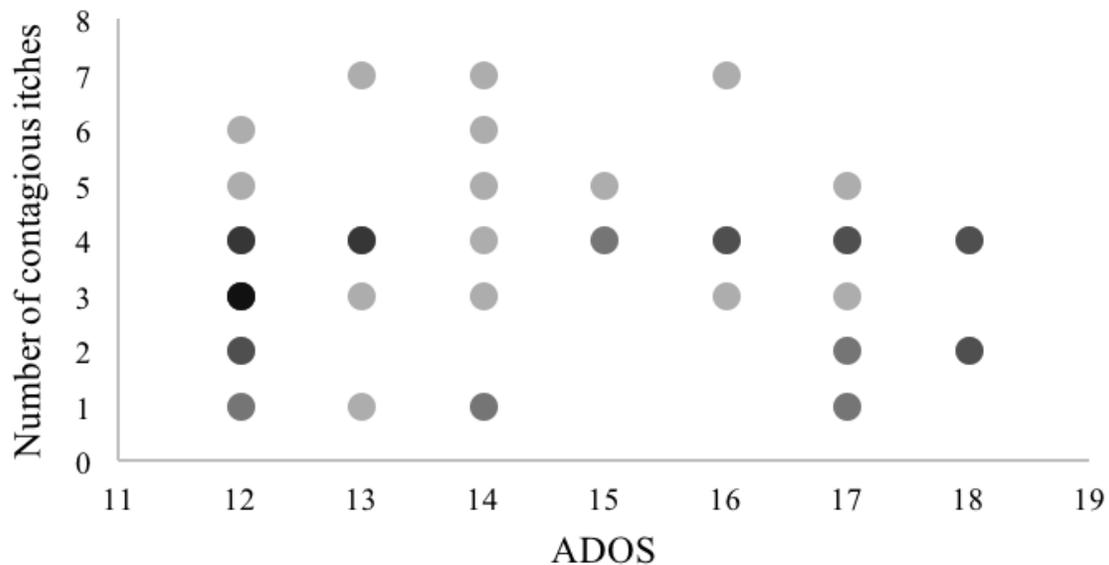be positively correlated with number of contagious itches.

Figure 4. Each point represents the ADOS score and number of contagious itches of an individual child

with ASD, with spots of increasing opacity indicating multiple children who had the same ADOS score

and number of contagious itches. Correlation quite insignificant (-0.022) .

A correlation test run on the data matching ADOS score with number of contagious itches for each individual in the ASD group resulted in almost no correlation between the two components (-0.022), displayed in *Figure 4*.

Discussion

Implications on mirror neuron theory

While this study is behavioral in nature, it was hoped that our results would elucidate some contribution to the debate on whether mirror neurons are formed automatically during early development, or formed throughout life as a product of associative learning. *Hypothesis A* sought to compare contagion of itching in children with ASD to the already demonstrated reduction of contagious yawning and laughing in this population (Helt et al., 2010; Helt & Fein, 2016). If the results had demonstrated that itching was impaired alongside the other contagious behaviors, this would have suggested that mimicry, and thus mirror neurons, are overall impaired in individuals with ASD. However, itch contagion was instead shown to be entirely intact in individuals with ASD—increased, even. In context of the mirror neuron debate, these results demonstrate clearly that mirror neurons are not *entirely* impaired in individuals with ASD.

These results alternatively suggest that, since contagion of different types of behaviors clearly varies in children with ASD, perhaps there exists a variation in mirror neuron density relating to different behaviors as well. Individuals with ASD may be more experienced—and thus have more associative learning—with itch behaviors than with yawning and laughter, and thus the discrepancy in contagion is directly related to discrepancies in both associative learning of and mirror neuron density related to these behaviors. Thus, the results of *Hypothesis A* suggest that mirror neurons are not formed altogether during early development, but are instead formed differentially over time, based on associative learning of different behaviors. Since it is clear that overall, individuals with ASD experience less associative learning of behaviors than their TD counterparts, it does make sense that mirror neuron density would be overall reduced in this

population, as has been previously demonstrated in EEG studies (Oberman et al., 2005). It is also

possible, though, that while certain populations of mirror neurons related to certain behaviors

may be severely impaired in ASD, other mirror neuron populations may be intact, or even

enhanced.

It was then hypothesized (*Hypothesis B*) that perhaps the reason for this discrepancy in

associative learning is due to the localization of these behaviors; yawning and laughing occur in

the facial region, which individuals with ASD tend to avoid looking at directly, but itching can

occur in regions distant from the face, which individuals with ASD are more comfortable

looking at. *Hypothesis B* thus tested to see if itches stimulated close to the face were less

contagious for children with ASD than itches stimulated distant from the face. If this hypothesis

was demonstrated to be correct, this would have continued to support the aforementioned

conclusion that mirror neurons are developed due to associative learning, because individuals

with ASD should be more likely to exhibit contagion in response to behaviors that they have

observed more frequently—behaviors which are unaffected by reduced face gaze. However,

Hypothesis B was not supported. This means that the difference in required facial visualization

between these behaviors is not the cause of their observed differences in contagion.

The results to these two hypothesis tests conclusively suggest two ideas. One is that

mirror neurons seem to be developed *not* altogether during early development, but instead as a

product of associative learning. Thus, mirror neurons may be differentially impaired in

individuals with social disorders like ASD, based on differential reduction in certain social

behaviors that would normally lead to associative learning. The second conclusion is that the

discrepancy seen between contagion of itch and contagion of yawn and laughter are not

necessarily due to the reduction of face gaze seen in ASD. There must, then, be other

explanations for the increased itching seen in children with ASD. These explanations could be

based in differences of neural wiring caused by approach-avoid system damage, empathy

deficits, sensory hypersensitivity, or differing developmental timelines of various behaviors in

ASD.

Approach-avoid system damages

Initially, the increase in contagious itching in children with ASD seems contrary to the

decrease in contagious yawning and laughing. However, it is possible that these behavioral and

mirror neuron density-level differences between children with ASD and TD children are due to a

common cause: an overall impairment in the approach-avoid system. Usually, individuals

possess an unconscious tendency to classify all stimuli as "good" stimuli, which should be

approached, or "bad" stimuli, which should be avoided (Chen & Bargh, 1999). The classification

of stimuli as such typically leads to an increase in mimicry of "good," or positively associated

behaviors, and a decrease in mimicry of "bad," or negatively associated behaviors. This

approach-avoid system may potentially be impaired in individuals with ASD, which would mean

that it is more difficult for this population to learn behaviors related to positively associated

stimuli, and more difficult to suppress learning of behaviors related to negatively associated

stimuli.

The actions of yawning and laughing indicate that an individual is relaxed, and thus, both

behaviors thus depict a positive affect. These types of positively associated behaviors should

normally invoke an approach response, but instead invoke reduced mimicry in children with

ASD. If there exists an impairment to the approach-avoid system in ASD, however, it is possible

that children with the disorder simply have trouble internalizing learned behaviors associated

with positive. Further, then, it would also be more difficult for children with the disorder to

suppress learning of behaviors with a negative association, such as itch, which connotes

discomfort or disease and should typically be avoided.

Prior studies have shown that children with ASD are often inconsistent when categorizing

stimuli as positive or negative, even when the stimulus is unchanged (Feil-Seifer & Mataríc,

2011). This inconsistency seems to reflect an overall inability to accurately categorize stimuli as

good or bad, and thus may ultimately illustrate an impairment of the approach-avoid system in

individuals with ASD. Future studies should explore if social contagion in ASD varies by

positive or negative association with the signal. fMRI—a technique used to examine brain

activity throughout distinct regions—could reveal different relative densities of mirror neurons in

distinct subpopulations, which could be related to the approach-avoid system in ASD. It is

possible that populations of mirror neuron activity related to positively associated mimicry will

be diminished in individuals with ASD, but mirror neuron activity related to negatively

associated mimicry will be enhanced.

Empathy deficits

Empathy, the ability to share the feelings of others, has been demonstrated to be reduced

in individuals with ASD, as measured by the MDEES (Mayer et al., 1999), the IRI (Davis,

1980), or by the Empathy Quotient, or EQ (Baron-Cohen & Wheelwright, 2004). Perhaps the

increase of itch contagion in children with ASD juxtaposed with the decrease of contagion of

yawning and laughter is due to a discrepancy in the amount of empathy needed to interpret

different behaviors. Laughter, in particular, is very clearly associated with a strong, happy

emotion. It would therefore make sense for learned mimicry of laughter to require a greater amount of empathy than itching, which seems to be a less emotionally associated behavior.

Previous studies on contagious behavior (Sorensen, 2017) have linked empathy with contagion of yawning and itching as measured by the IRI in populations with ASD-like traits. In order to expand upon the literature connecting empathy to contagion, our participants were given the MDEES in addition to the SSP, ADOS, Stanford-Binet, and video clip exposure. If our data on emotional empathy for this cohort is analyzed in the future, it could potentially demonstrate a correlation between low empathy levels and both low contagion of laughter, and high contagion of itch. This correlation would support the idea that perhaps itch contagion requires less empathy to learn than laugh contagion.

Sensory hypersensitivity

It is possible that the increase seen in contagious itch in children with ASD is due to an increased tactile sensitivity, or sensory hypersensitivity in this population (Güçlü, Tanidir, Mukaddes, & Ünal, 2007; Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009). Children with ASD demonstrate a higher impact of uncomfortable tactile stimuli (e.g. itchy tags on clothing) than their TD counterparts (Baron-Cohen et al., 2009). As has been previously explained, the differences in contagion between itching, yawning, and laughter seem to be due to a discrepancy in associative learning. It is possible that children with ASD are exposed to yawning, laughing, and itching equally, but find it easier to learn itching behaviors because they are already quite familiar with itch, and experience this sensation naturally on their own. This phenomenon has already been seen in individuals with atopic dermatitis, who are more likely to experience contagion of itch than healthy individuals (Schut et al., 2015).

Baseline levels of itching were not increased in children with ASD, as evidenced by the

fact that children with ASD showed the same amount of spontaneous itching during laugh and

yawn stimulus video clips as the TD children (*Figure 1*). However, information regarding

sensory sensitivity was collected for each participant using the SSP. If this data is analyzed in the

future, it is possible that a correlation would exist between sensory sensitivity, as measured by

the SSP, and contagion of itch in children with ASD.

Developmental timelines

It is possible that learning to mimic yawning and laughter are simply less evolutionarily

advantageous to an individual than learning to mimic itching, and thus, mirror neurons

associated with itch may just be developed on a more urgent timeline than those associated with

yawn and laughter. While laughter can improve social interactions and can thus foster

cooperation and friendship (Mehu & Dunbar, 2008), this mimicry may be far less important than

learning to recognize and understand that another individual in the group is uncomfortable or has

a disease, which is evidenced by itching. Perhaps, then, learning to mimic yawning and laughter

is impaired in children with ASD but learning to mimic itching is not, because formation of

itch-related mirror neurons occurs earlier in the developmental timeline. Perhaps mirror neurons

associated with yawning and laughter require more associative learning, and more social

interaction, than mirror neurons related to itch, which are arguably more evolutionarily important

for the individual. Ultimately, understanding of itch in others may just be more beneficial to the

individual than understanding of happiness. Future studies could examine this concept by

exploring the development of contagion over time in a cohort of young children with ASD. The

aforementioned idea of evolutionary importance would be supported if these hypothetical studies

showed children with ASD increasing contagion of itch as they grow older, but not increasing

contagion of yawning and laughter.

Limitations of current study

Hypothesis C explored the possible correlation of itch contagion and ASD severity, as

measured by the ADOS. While the results to *Hypothesis C* showed no correlation, it is possible

that these results are confounded by the generalized nature of the ADOS score. The ADOS

Module 3 compiles the results of 14 different behavioral prompts into one overall score

indicating ASD symptomatology of the individual (Lord et al., 2000). While this score is

reasonably reliable, it may be useful to further examine each participant's responses to the

individual behavioral prompts because individuals with ASD differ widely across a spectrum of

personal traits and experiences. An item analysis of data from each ADOS section could

elucidate specific characteristics of ASD that are associated with increased contagious itch,

which ultimately would be more useful information than a correlation with the overall ADOS

score.

Future directions

As explored above, the increased contagion of itch in children with ASD is largely

unexplained, but has many potential theories that could be explored through additional analysis

of our cohort, and through future studies in other labs. Future analysis of our cohort could

present a correlation between sensory sensitivity, as measured by the SSP, and contagion of itch

in children with ASD, which would support the idea that our results were due to sensory

hypersensitivity in ASD. Our data on emotional empathy, as measured by the MDEES, could

potentially demonstrate a correlation between low empathy levels and both low contagion of

laughter, and high contagion of itch, which would inform the idea that learning different behaviors requires different amounts of empathy. An item analysis of data from each section of the ADOS could elucidate specific characteristics of ASD that are associated with increased contagious itch.

Future studies in other labs could employ fMRI to potentially reveal different relative densities of mirror neurons in positively versus negatively associated subpopulations. Other labs could conduct a longitudinal study exploring the development of contagion over time in a cohort of young children with ASD, which would provide information for the idea of differing developmental timelines for different behaviors, based on prioritized evolutionary importance.

Ultimately, while this study has provided new data on contagion in ASD, and may inform the mirror neuron debate, there is still substantial research to be conducted on these topics.

Conclusion

Contagious itching is not only intact in children with ASD, but it is *higher* than that seen in TD children in this study (*Figure 1*). These results suggest that mirror neuron functionality is not entirely impaired in ASD, which counters previous beliefs in the field that were based on impairments in mimicry of facial expression, yawning, and laughing. The increase observed in contagious itching in this population does not seem to be based on proximity of the stimulus itch to the face (*Figure 2*), nor on ASD severity based on scores on the ADOS (*Figure 3*). Future analyses of this cohort will examine differences in empathy and tactile sensitivity, and will break down ASD diagnoses into characteristics to explore if specific traits are correlated with contagion of itch. Further research could additionally provide implications on mirror neuron theory by identifying distinct mirror neuron subpopulations associated with positive and negative behaviors, and by examining the development of contagion through early life.

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