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Article

Obscurity of eyebrows influences recognition of human emotion and impacts older adolescents

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SUMMARY

Facial features (e.g. eyebrows, mouth) give important visual cues to help convey emotions such as happiness, anger, and sadness. It is ultimately through these face-to-face interactions where accurate interpretation and response to facial expression benefits social-emotional development by helping humans foster strong interpersonal relationships. The problem is that recent societal factors, such as increased smartphone/social media use and the Coronavirus pandemic have reduced the opportunities to engage in natural, face-to-face social interaction. The purpose of our study was to determine whether the presence of eyebrows in photographs is essential for interpreting emotion and whether participant accuracy and/or reaction time (RT) is age-dependent. We hypothesized that eyebrow presence in unaltered control photographs would enhance participant recognition of emotion compared to experimental photographs with removed eyebrows and that participant accuracy and RT would differ by age group, especially between adults (21+ years) and adolescents (12-18 years). Our findings revealed that removing eyebrows results in a significant decrease in participant accuracy to recognize anger from experimental facial images. In addition, upper school (US) adolescents (15-18 years) were more likely to misidentify emotions from eyebrow-obscured photographs compared to middle school (MS) adolescents (12-14 years) and adults (21+ years). Finally, US adolescents took significantly longer (> 5 seconds) to identify emotion from eyebrow-obscured photographs of the human visage compared to US adolescents shown the same unaltered control photographs. Therefore, the age group studied that is at most risk of facial misinterpretation and delayed response to facial cues which help foster interpersonal relationships are US adolescents.

INTRODUCTION

Human beings are characterized as primates that live in structured social groups and rely on group interactions to communicate with one another (1). Although we like to think of ourselves as complex creatures, primates share many similarities in social behavior, such as aggression and show affiliation with other members of the animal kingdom that have less complex brain structure, including insects like ants (2). The social behaviors that we share with animals do serve an important biological purpose. Even Charles Darwin acknowledged that similar social traits observed in animals and humans play a crucial role in the species' ability to survive (3). These findings inspired the modern scientific study of emotions, resulting in new scientific disciplines such as psychology to further our understanding of the human mind and behavior (4).

As social creatures, humans communicate in various ways. Studies indicate that communication can be verbal, such as spoken language as well as nonverbal, such as body language (5). This social behavior, whether conveyed or interpreted, is a beneficial communication tool (5). Humans have evolved to communicate in groups as it contributes to our reproductive success (6). Nonverbal communication (i.e. body language) is also important as it creates impressions to one's audience, such as confidence, awkwardness, or anxiety and provides information to others about our feelings, intentions and attitudes (7). For example, the crossing of one's arms may convey frustration whereas open arms may convey comfort in social settings (8). Furthermore, our ability to interpret facial features (e.g. eyebrows & mouth) is a sign of emotional intelligence and helps guide our response in social interactions. When successfully done, responding to another's facial expressions can help foster strong interpersonal relationships and has been linked to improving health and well-being across an individual's lifespan (9).

Among nonverbal communication signals, the human visage (i.e. face) plays a pivotal role in social interaction (10). Certain facial expressions (happiness, anger, sadness and surprise) are similarly displayed across different cultures, resulting in a universal communication tool (11). During social interactions, it is from anatomical positioning of the mouth, eyebrows and forehead creases that one collectively provides emotional cues. For example, the universal happy face is made with facial muscles that position the mouth, lips and teeth into a smile yet our eyebrows do not move very far upward, downward or into a furrowed brow formation (12). Although the facial expression of happiness relies primarily on mouth position, for other emotions, it is the eyebrows that play a more important visual role. Previous studies report that humans display anger through a downward motion of the brow muscles, causing the eyebrows to furrow and draw downward and together (13). Known as the frontalis facial muscles, they control eyebrow shape/position and are necessary for conveying visual cues such as anger and surprise (14). These

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muscle movements result in wrinkling between the eyebrows to convey anger and distinct upper forehead creasing patterns to convey sadness (13). Altogether, the positioning of facial muscles, mouth and eyebrows collectively convey social cues to help maximize facial cue interpretation and response in social settings (12- 14).

Taking into consideration that social behavior is beneficial, conditions such as autism spectrum disorder, social anxiety disorder and borderline personality disorder happen to limit social interactions (15). Studies report that abnormal social functioning is a central symptom of these disorders and originates from an inability to accurately interpret visual expression (2,16). Children with behavioral problems have difficulty identifying when someone is mad, happy, etc. resulting in an inability to socialize well with others and perhaps, social isolation (17). This raises the question of whether modern societal factors of the Information Age (1970-present) can impede one's ability to interpret and respond to emotional facial cues during face-to-face social interaction. In addition, since members of a population are at different stages in their social development, one's age group could put them more at risk of misinterpreting facial visual cues.

There are several social factors that can impede or enhance our ability to understand and respond to facial emotional cues such as the amount of time that one is socially conditioned to spend in full face-to-face interactions. Previous studies have demonstrated heightened ability amongst hearing-impaired/American sign language (ASL) populations for reading facial expressions and recognizing core human emotions from facial cues (18). These populations routinely rely more heavily on facial expression as a communication tool and therefore have more exposure with face-to-face interactions (18). It is also important to note that social media sites have become a popular communication source in modern society yet trend away from face-to-face social interaction. One study reported that the use of social media worldwide increased from 0.97 billion to 2.48 billion users between 2010-2017 (19). Another study reports that the average age for a person to sign up for a social media account was 12.6 years in 2018 (20). In the same study, 56% of persons (8-18 years) in the United States had access to social media as a communication outlet (20). These social media sites, such as Facebook, Snapchat and Instagram are only a few examples of message-based platforms that offer ways to communicate, connect and interact with one another. However, these social media platforms cause a break in the natural development of visual social skills because their main source of communication is through written text and trend away from in-person visual interaction (21). Ultimately, text-based social media is more likely to result in the misinterpretation of one's words for an incorrect emotion and negatively affect the development of strong interpersonal relationships (21).

There are also health related factors that impede routine face-to-face interaction and correlate with a reduction in facial recognition and response. A recent example occurred during the 2020 Coronavirus disease pandemic (COVID-19). The abrupt emergence of facemasks significantly affected social interactions, reducing emotional recognition by up to 30% (22). Key visual expressions of the lips and the mouth were concealed by facemasks and lowered our ability to interpret nonverbal social cues. In one study, covering the mouth impacted the physician-patient relationship as it hid both the patient's fear, as well as the doctor's empathy (23). COVID-19 did not just affect social interactions within healthcare. Many other groups, such as students and educators, had to socially interact with face masks during the pandemic. In-person masking and alternative (online) platforms, such as Zoom, became a staple for educational instruction and social interaction (24). However, students were not always engaging in the routine practice of conveying and interpreting facial cues. For example, many students hid their face over Zoom, electing for a black-screened background. They also relied more heavily on talk and written text for communication. As a result, adolescents spent the majority of their time during COVID-19 either socializing online without natural, face-to-face practice or in-person with half-hidden faces (25).

Although the eyes and eye region of the face play an important role in deriving social cues, their role was even more influential during COVID-19. Previous studies report that eyebrows are considered the second most important facial feature, after the eyes (26). One study reported that the absence of eyebrows in familiar faces significantly disrupted the ability of study participants to recognize those faces (27). Similar to the disruption of social interaction that facemasks caused during the COVID-19 pandemic, another study reported that removing the mouth caused study participants to turn towards the eyes (26). As mask exposure increased humans became increasingly reliant on the eye region for interpreting visual facial cues (28).

The COVID-19 pandemic serves as a socially trying time in human history. Not only do post-pandemic studies report that the removal and/or obscurement of key facial features (mouth & eyebrows) correlates with misinterpreting visual emotional cues during social interaction, they also indicate an earlier introduction of adolescents to social media post COVID-19 (29,30). In one study, there was a 17% increase in screen time amongst 9–17-year-olds from 2019-2021 (29). In addition, the proportion of 9–12-year-old survey respondents who used social media increased from 31% in 2019 to 38% in 2021 (29). This shift has been aided by an increase in smartphone possession by those in adolescent age groups (30). In addition, smartphones and social media are compelling for adolescents as they are at a time in their development when brain region sensitivity spikes with a drive for attention, feedback and reinforcement from their peers (31). Many adolescents with feelings of vulnerability in social situations have and continue to rely on social media to routinely seek out and maintain interaction with their peers, find online support groups and explore their own identities as they navigate towards autonomy from their parents (32).

The purpose of our study was to determine whether the presence of eyebrows in facial photographs of core human emotions (happiness, sadness, confusion, surprise & anger) serves an essential role in the interpretation of visual facial cues and whether the accuracy and/or reaction time (RT) of interpretation was also age dependent. We hypothesized that eyebrow presence in control photographs would enhance control group participant recognition and RT to five core human emotions compared to a group shown the same experimental facial photographs with obscured eyebrows. We also hypothesized that participant accuracy and RT would differ by age group, especially between adults (21+ years) and adolescents (12-18 years).

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Our data indicates that eyebrows are an essential and age-dependent feature for human interpretation of negative (anger & sadness) and positive (happiness) emotions. We found a significant misidentification of anger between our total population's analysis of experimental vs. control photographs. Our total population also trends towards delayed participant RT when identifying happiness from experimental photographs. Individual age group findings demonstrate the importance of facial interactions with eyebrows, primarily in 15–18-year-old upper school (US) adolescents, for rapidly and accurately deriving social cues from five core human emotions. US adolescents evaluating eyebrow obscured facial photographs had the longest reaction time and lowest percent accuracy compared to middle school (MS) and adult age groups. This difference was even stronger when identifying or reacting to negative emotions like happiness, sadness and anger. Consequently, our study suggests that US adolescents (15-18 years) may be the age group studied at most risk of being able to quickly interpret and respond to facial expression of core human emotions during in-person social interactions.

RESULTS

Our study examines whether eyebrow presence in facial photographs of five core human emotions (happiness, anger, sadness, confusion & surprise) was essential to participant response percent accuracy (%) and reaction time RT (seconds). Participants were either shown five facial images of human emotion with eyebrows present in control photographs or the same five images with obscured eyebrows in experimental photographs. The participants were further divided into subset age groups so that participant response to either control or experimental photographs was controlled for similar biological sex and age (**Tables 1 & 2**).

We conducted Univariate ANOVA and Tukey's Post Hoc tests ($\alpha \leq 0.05$) for participant percent accuracy of control and experimental photograph interpretation depicting five core human emotions and found no statistical differences between the six age groups ($F_{5,59}$ =1.30, p = 0.277) as well as between total population accuracy of combined ages for interpretation of control and experimental photographs ($F_{1,59}$ = 0.94, p = 0.34) (**Figure 1**). The US adolescent age group showed the greatest decline (14%) in percent accuracy

Photograph Type	Male	Female	Average Age (years)	Age Range (years)
Control	16	14	24.43	12-60
Experimental	13	17	24.17	12-54
Total	29	31	24.3	12-60

Table 1: Total population age group statistics by photograph type. Participant (n=60) statistics of biological sex, average age and age range in years based on response to control photographs (with eyebrows) or experimental photographs (without eyebrows).

		Control Photographs	Experimental Photographs
Adults	Participants (Male)	5	4
	Participants (Female)	5	6
	Average Age (years)	43.2	43.1
	Age Range (years)	29-60	32-54

		Control Photographs	Experimental Photographs
US Adolescents	Participants (Male)	6	5
	Participants (Female)	4	5
	Average Age (years)	16.7	16.3
	Age Range (years)	15-18	15-18

		Control Photographs	Experimental Photographs
MS Adolescents	Participants (Male)	5	4
	Participants (Female)	5	6
	Average Age (years)	13.4	13.1
	Age Range (years)	12-14	12-14

Table 2: Age group statistics by photograph type. Participant (n=60) age group statistics of biological sex, average age and age range in years based on assignment to evaluate control photographs (with eyebrows) or experimental photographs (without eyebrows).

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when interpreting experimental photographs compared to control photographs.

We also conducted the Univariate ANOVA and Tukey's Post Hoc statistical tests ($\alpha \leq 0.05$) for participant RT to identify five core human emotions from control and experimental photographs and found a significant difference across the six groups ($F_{5,59}$ = 3.11, p = 0.02) with Post Hoc (p < 0.01) indicating a significant delay in US adolescents (15-18 years) (**Figure 2**). The US adolescent group shows the greatest delay in RT, taking an additional 5 seconds to identify emotion from an eye-brow obscured collection of experimental photographs compared to unaltered control photographs. No statistical difference in RT occurred between total population of combined ages for response to control and experimental photographs ($F_{1,59}$ = 1.61, p = 0.21).

Statistical analysis of participant response to each individual emotion type was evaluated through Univariate ANOVA and Tukey's Post Hoc statistical tests ($\alpha \leq 0.05$). Happiness was the most-recognized emotion for average participant accuracy of control (97%) and experimental (93%) photographs (**Figure 3a**). Although the US adolescents were the only age group to show a decrease in accuracy (10%), statistical analysis does not show significant differences across the six age groups ($F_{5,59}$ = 0.60, p = 0.70) nor total population accuracy between analysis of control vs. experimental photographs ($F_{1,59}$ = 0.34, p = 0.56) (**Figure 3a**). Our data indicated a statistical difference in RT across the six age groups ($F_{5,59}$ = 4.23, p < 0.01) with Post Hoc tests showing significantly delayed RT in US adolescence identification of happiness from experimental photographs to all five other groups (p < 0.01-0.03) (**Figure 3b**). In addition, our data also indicated that the presence of eyebrows is weakly essential ($F_{1,59}$ = 3.76, p = 0.06), with a delayed RT response in our total population to experimental photographs of happiness (**Figure 3b**).

When it comes to the emotion of anger, our data indicates a significant difference ($F_{1,59}$ = 4.17, p = 0.05) for our total population's accurate interpretation of anger (**Figure 3c**).

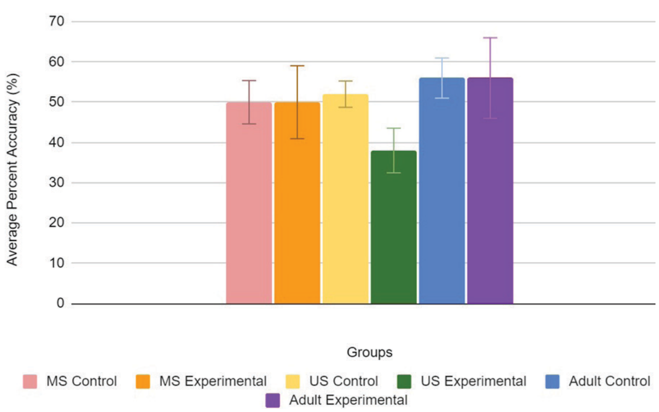

Figure 1: Average percent accuracy for recognizing human emotion by age group. Average percent accuracy for recognizing five core emotions (happiness, anger, sadness confusion & surprise) by age group participant (adult, upper school (US) adolescent and Middle school (MS) adolescent) response to unaltered control photographs and experimental (without eyebrows) photographs (n=10 persons & 50 responses per group). Univariate ANOVA with Tukey's Post Hoc tests ($\alpha \leq 0.05$) between age groups ($F_{5,59}$ = 1.30, p = 0.277).

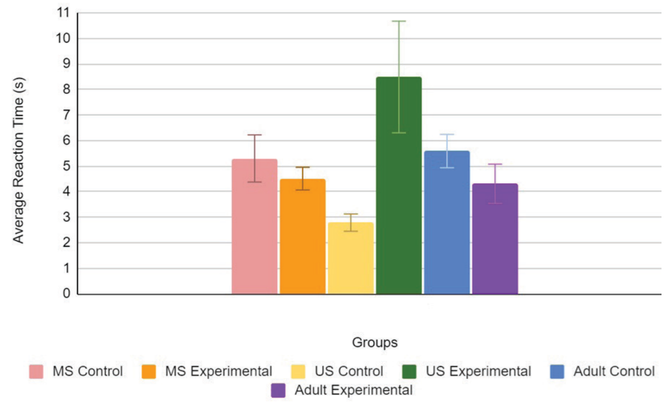

Figure 2: Average reaction time (RT) to predict human emotion from facial by age group. Average RT in seconds (s) for recognizing five core emotions (happiness, anger, sadness confusion & surprise) by age group participant (adult, US adolescent and MS adolescent) response to unaltered control photographs and experimental (without eyebrows) photographs (n=10 persons & 50 responses per group). Univariate ANOVA with Tukey's Post Hoc tests ($p \leq 0.05$) show differences between the six age groups ($F_{5,59}$ = 3.11, p = 0.02). A significant difference was shown in the US age group (control vs. experimental) in a Post Hoc test (p < 0.01). US participants took an additional 5 seconds to identify emotion in experimental photographs compared to US participants reviewing control photographs.

Furthermore, US students were the only age group to misinterpret eyebrow obscured images of anger 100% of the time, for 0% accuracy (**Figure 3c**). Statistical analysis of participant RT to each individual emotion type shows no statistical percent RT differences for the emotions of confusion and surprise (results not shown) as well as anger (**Figure 3d**). There are also no significant differences in percent accuracy for the emotions of sadness, confusion and surprise though US adolescents were the only age group to misinterpret eyebrow obscured images of sadness 100% of the time, for 0% accuracy (**Figure 3e** and results not shown). For the emotion of sadness, our data indicated a statistical difference in reaction time across the six age groups ($F_{5,59}$ = 2.49, p = 0.04) with Post Hoc tests showing a significant delay in US adolescents' RT to identify images of sadness from experimental photographs (p = 0.03) than those of US adolescents with control photographs (**Figure 3f**).

DISCUSSION

The purpose of this investigation was twofold: to determine whether the presence of eyebrows is essential for understanding visual social cues and also whether age further influences the interpretation of facial expression. We compared average participant percent accuracy (%) and RT (seconds) to randomized photographs of five core human emotions (happiness, sadness, anger, confusion & surprise). Adult, US adolescent and MS adolescent participants viewed unaltered control photographs of the human visage while a second group of same-aged participants viewed the same images with obscured eyebrows as experimental photographs.

Although our study did not show a statistical difference in accuracy for identifying five core emotions between control and experimental photographs. our total population showed

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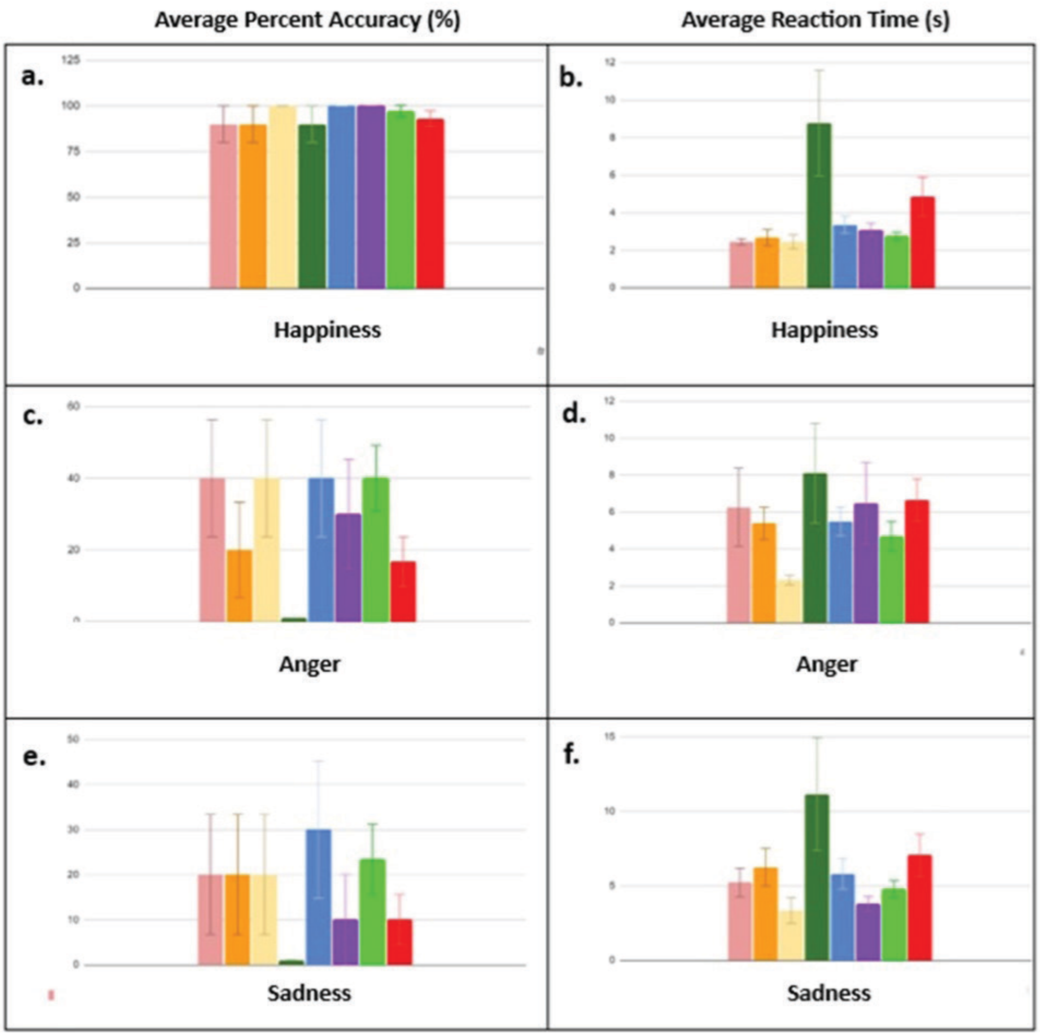

Figure 3: Average percent accuracy and reaction time of facial cue interpretation by age group and total population for positive and negative emotions. Adult, US adolescent, MS adolescent and total population average participant accuracy (%) and reaction time (RT) in seconds (s) for identifying the positive emotion of happiness (**a** & **b**) and negative emotions anger (**c** & **d**) and sadness (**e** & **f**) from unaltered control photographs and experimental photographs (no eyebrows). Left-side graphs (**a**, **c** & **e**) show average percent accuracy and right-side graphs (**b**, **d** & **f**) show RT. Univariate ANOVA with Tukey's Post Hoc tests ($\alpha \leq 0.05$) show significant findings for (**b**) age group RT to happiness ($F_{5,59} = 4.23$, $p < 0.01$) with delay in US adolescents ($p < .01$-$.03$) to remaining five groups and a weak significance (**b**) in total population RT delay to experimental photographs of happiness ($F_{1,59} = 2.23$, $p = 0.06$). Total population accuracy is significantly decreased (**c**) when interpreting experimental photographs of anger ($F_{1,59} = 4.17$, $p = 0.05$). A statistical difference (**f**) in RT between age groups ($F_{5,59} = 2.49$, $p = 0.04$) with a significant delay in US adolescent RT to experimental photographs ($p = 0.03$) compared to US adolescent control photographs.

a statistically significant misinterpretation of anger from experimental photographs (**Figure 1 & 3c**). An explanation for our findings is that when humans convey negative emotions, such as anger and sadness, the frontalis muscles of the brow move eyebrows into a downward motion, bringing them close together in distinct V-shaped forehead creasing (**Figure 4a & 4b**). Therefore, our population has been conditioned to look for and identify anger by searching for eyebrow position/placement as the key facial feature and removing them decreased participant ability to differentiate anger from other types of emotion.

Our study's non-negative emotions (happiness, surprise and confusion) did not cause significant differences in participant misinterpretation of experimental photographs. For example, the positive emotion of happiness was the most accurately-recognized emotion type amongst all age groups, resulting in a 97% accuracy in the control group and a 93% accuracy in the experimental group (**Figure 3a**). Similar to human emphasis on eyebrows and forehead creases for conveying and interpreting anger, we reason that humans rely on the mouth when providing and interpreting visual facial cues of happiness (**Figure 4c**). The similar and sometimes less apparent use of the mouth for conveying and interpreting surprise and confusion likely provided enough visual cues in experimental photographs to not significantly disrupt participant accuracy (**Figure 4d & 4e**). Therefore, eyebrows are not as essential for conveying and accurately interpreting emotions of happiness, confusion and surprise as they are for anger.

Regarding age-related differences in our population,

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Figure 4: Sampling of five core human emotions from control and experimental photographs. Left side images show unaltered control photographs of the human emotion for (**a**) anger, (**b**) sadness, (**c**) happiness, (**d**) surprise and (**e**) confusion. Right side images are the eyebrow obscured experimental photographs of the same emotion from the same individuals.

removing eyebrows from experimental images had the greatest impact on US adolescents (15-18 years). The US adolescent group showed a statistically significant delay in RT, taking an additional 5 seconds to identify emotion from an experimental photograph collection of five core human emotions (**Figure 2**). The greatest delays in US adolescent RT to experimental photographs occurred with experimental images of happiness, anger and sadness (**Figure 3b, 3d & 3f**). In addition, the delay in US RT to experimental photographs of happiness was significant enough to result in a weakly significant delay in our total population's RT to experimental images of happiness (**Figure 3a**). There are also percent accuracy trends that are worth noting of the US adolescent age group such as the largest age group decline (14%) in percent accuracy between interpretation of experimental vs. control photographs for all five emotions. US adolescents also misinterpreted experimental photographs of anger and sadness 100% of the time, for 0% accuracy (**Figure 3c & 3e**). Finally, despite the high accuracy throughout all age groups for identifying happiness in photographs, US adolescents were the only group to show a decline (10%) in accuracy when analyzing experimental photographs of happiness compared to control photographs (**Figure 3a**). This data suggests that US adolescents may not be experiencing the traditional social-emotional factors that provide opportunities to engage in routine, full face-to-face exposure during social interactions.

Since humans rely on facial visual cues to analyze human emotion, we believe the removal of the eyebrows causes participants to place emphasis on alternative visual cues (e.g. mouth, forehead creases and eyes). As a result, humans are more likely to take additional time to look for these alternative facial cues before identifying an emotion type and this was significantly demonstrated in the US adolescent age group. Our data may also suggest that the delayed average RT in US adolescents could be a result of non-traditional social factors of the Information Age, such as online social media (e.g. Instagram, Snapchat etc.) and imply that human communication and connections are in the process of evolving. Both the accelerated rise in the number of adolescents with smartphones and social media use during/post COVID-19 have offered this age group an alternative way to interact, engage and communicate with their peers. However, social media sites and text-messaging do not replace traditional in-person interaction and rely on written text as the primary communication tool. This reduces the opportunity to engage in and practice traditional face-to-face social interaction. Consequently, US adolescents who routinely communicate through social media and text, may be at a greater risk of misinterpreting and significantly delaying their response time to core facial signals during in-person social settings

Finally, the collective increase in both the RT and misinterpretation trends of facial cues by US adolescents in experimental photographs could be explained by considering a unique developmental delay in adolescents as a result of the COVID-19 pandemic. This age group was in MS when the COVID-19 pandemic surged and often engaged in routine (in-person) social interactions where mouths were not visible, yet eyebrows were. In addition, online educational platforms were underutilized for visual and full face-to-face interactions between educators and students. The current US age demographic may have relied on deriving facial cues during COVID-19 by hyper-focusing on eyebrows at a time in their social development when face-to-face interaction would be natural and ideal for facial cue interpretation. The remnants of this hyperfocus on eyebrows could likely have carried into present-day times in our US demographic despite masking no longer being required post-vaccination. This may also explain why MS adolescents, who also use social media as

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a communication outlet, did not show statistically different accuracy and RT results. Current MS adolescents may not collectively have the same amount of social media platform exposure as the US adolescents in our study and are in post COVID-19 social settings where full face-to-face interactions naturally occur since masking is no longer routinely required.

Our study questioned the use and interpretation of facial expression as a communication tool between humans. However, our study did not recruit or control for sensory-impaired human participants such as hearing-impaired/ American Sign Language (ASL) populations that rely more heavily on facial expressions as a communication tool. Consequently, hearing-intact populations, such as the participants in this study, may show a decrease in accuracy compared to an ASL population, especially in US adolescents who may rely less on social media than on routine face-to-face interactions to communicate. Conversely, an ASL population may also show delayed RT to experimental photographs since they may be socially conditioned to spend more time navigating all facial anatomical clues (teeth, lips, eye wrinkles, etc.) when a key feature, such as eyebrow anatomy, is no longer visible. Their results may present more similarly to our US adolescent group who showed delayed RT when identifying experimental photographs because both groups would take more time to identify emotion by maximizing their search for additional facial cues.

Our study more specifically questioned the impact of eyebrows when interpreting human emotion from facial photographs and indicate that removing the key facial feature of eyebrows from facial images of anger significantly reduces total population accuracy. Should our study have focused on the mouth, a key feature in facial recognition of happiness, it is possible that removing mouths from photographs could significantly impact our total population's interpretation of happiness. Since humans are socially conditioned to hyperfocus on the mouth to identify happiness, we would also imagine delayed participant RT to experimental photographs with removed mouths. On the other hand, removing the mouth from images of anger, an emotion that emphasizes eyebrows as the key feature, would not necessarily result in a decrease in participant accuracy or RT in the total population. Removing both the mouth and the eyebrows from experimental photographs would most likely plummet participant accuracy and significantly delay RT in our total population as participants would have to spend more time to seek out and analyze non-key facial features. The implications of our findings are cautionary for present day adolescents that are replacing in person, face-to-face social interaction with text-based social media outlets. Although both are means of communication, they are not an even swap of visual human interaction.

To further this experiment, a repeat of the test for the current MS adolescents once they have reached the 15–18-year-old age group would be valuable to determine if they also show similar accuracy and RT as the US adolescents in this study. As the COVID-19 pandemic has subsided, similar results in a repeat study may imply that long-term use of social media platforms for communication is a (time-dependent) societal factor of the Information Age can delay adolescent response and lessen their accuracy to facial cues. In future experiments, we would also consider the difference between participant's biological sex. Although we controlled for a similar number of males and females in all groups evaluated during this study, we did not test the differences between males and females. Previous studies have shown that females are more accurate than males at identifying emotion type through visual cues of the human visage (33). Therefore, participants could be grouped based on biological sex rather than by age group and then analyzed for average percent accuracy and RT.

A limitation in our study was how the participant RT was recorded. Some participants neglected to stop the clock when they were ready to identify the emotion. The experimenters had to keep a close eye on the clock and immediately stop the clock in the event a participant prematurely verbalized an emotion. We suggest that the administrator of the photographs starts a stopwatch when they show a visual to a participant and stop the stopwatch once they hear that participant verbalize an emotion. A second limitation to our study's conclusion is the low number of participants (n=60). Repeating our study by recruiting a larger cohort of individuals would help to ensure an easier identification and elimination of outliers in our experimental data and allow us to draw conclusions from a more accurate representation of our population.

Our study supports that eyebrows are important visual cues of the human visage, specifically for the accurate interpretation of emotion of anger. In addition, the US adolescent age group (15-18 years) shows the longest delay in RT and are more likely to misinterpret facial cues when eyebrows are obscured. It is possible that our study has identified a generational subset of individuals (current US adolescents) who are showing the social impact of reduced face-to-face interactions in modern society. COVID-19 socially separated our current US adolescents during a time in their social development when they would naturally develop interpersonal relationships with their peers in full face-to-face interactions. This, combined with earlier and increased use of smartphones/social media may negatively impact US adolescent social development from understanding and quickly responding to visual social cues of the face that can foster strong interpersonal relationships.

MATERIALS AND METHODS

Scientific Review Committee (SRC) for Human Subject Research

An SRC team was assembled from within the Tower Hill School with the following expertise: a school psychologist, an administrator/science department chair and a faculty member with a PhD in genetics and molecular biology. The SRC team provided as-needed council throughout the study with regards to working ethically with adult and minor human subjects.

Photograph Participant Recruitment and Control Group Photographs

Two female and two male adults signed a consent form to have pictures taken of their faces with an iPhone 13. All photographed adults were asked to tie their hair into a ponytail, wear a white t-shirt and stand in front of the same classroom wall. The five core emotions photographed (happy, sad, angry, confused, and surprised) from each adult participant resulted 20 pictures for the control group.

Editing of Experimental Group Photographs and Photograph Labeling

A second set of 20 prints were duplicated for the

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experimental group and were further edited by removing the presence of eyebrows using Adobe photoshop. All 40 images of faculty were printed on 8.5 x 11 in. white Cougar cardstock paper with color ink from Staples. The back of each photograph was labeled with a number and letter, ranging from 1A-5A or 1B-5B. The numerical categories represent the type of core emotion of each participant (1 -confused, 2 - surprised, 3 - happy, 4 - sad and 5 - Angry). An “A” next to the number represents the control group photograph (with eyebrows) and a B next to the number represents the experimental group photograph (eyebrows obscured).

Grouping and Randomization of Photographs

Within the control group of 20 photographs, 4 piles of 5 cards were assembled so that all of the photographs of the same core emotion were grouped together (e.g. 1A’s, 2A’s, etc.). The team then shuffled each group of photographs and randomly drew one from each core emotion pile until there were 4 unique piles of 5 photographs for each core emotion (e.g. 1A-5A). In order to differentiate between each unique pile, four different highlighters (pink, yellow, blue and green) were used to color the number and letter on the back of each photograph. The same combination of photographs from the control group piles were assembled, labeled (e.g. 1B-5B) and highlighted with the same colors for the experimental group.

Participant Recruitment and Groups

The team recruited a total of 60 participants (29 males and 31 females). Participants were recruited by word of mouth from Middle School (MS) and Upper School (US) science faculty as well as from announcements made to the Tower Hill School community during morning meetings. Each participant reviewed and electronically signed a participant consent form (Google forms). All parents/guardians for US and MS participants under 18 years submitted a signed consent form for their child to participate in the study. The 60 participants were then divided to control for similar biological sex and age representation between those assigned to review either experimental photographs (n =30) or control photographs (n=30) (**Table 1**). A total of 16 males and 14 females (n=30) were assigned to review control photographs and 13 males and 17 females were assigned to review experimental photographs (n=30). In total, 150 participant responses were analyzed from the control and experimental photographs. In addition, the participants were further separated into a subset of 3 distinct age groups in order to determine whether the accuracy and RT of participant response to control/experimental photographs were also age dependent (**Table 2**). The three age groups analyzed were MS Adolescents (12-14 years, n=20), US Adolescents (15-18 years, n=20) and Adults (21+ years, n=20). Similar to the total population, participants within each age group subset were divided to control for similar biological sex and age representation between those assigned to review either experimental photographs (n=10) or control photographs (n=10) (**Table 2**). In total, each age group subset provided 50 participant responses to analyze between their review of either control or experimental photographs.

Data Collection of Participant Response

A total of 10 participants from each of the three age groups (n=30) were assigned to evaluate the control photographs and the remaining 30 participants were assigned to evaluate the experimental photographs with obscured eyebrows. Each participant provided five responses by evaluating five photographs of core human emotions (happiness, sadness, confusion, surprise & anger) from either control photographs (n=150) or experimental photographs (n=150). To record participant response, the teacher mentor read aloud the same instructions to each participant. The teacher began a time on an iPhone stopwatch when the first photograph was shown to the participant. The participant would self-stop the timer on the same iPhone once they were ready to identify the emotion in each photographed image. The RT in seconds(s) and the participant’s verbal identification of the emotion were recorded by the student scientists. Verbal results that accurately correlated with the emotion category (1-5) were assigned a point value of “1” and inaccurate interpretations were assigned a point value of “0”. All control group participants were shown images 1A-5A and all experimental group participants were shown images 1B-5B. The results were analyzed based on control vs. experimental group participant responses for all individual emotion types and also compared between age group responses.

Data Analysis

We determined average percent accuracy by taking the number of correctly identified emotions (i.e. hits) from the control group (all ages), dividing them by the total number of participant responses (n=150) and adjusting the value to a percent. We also calculated the average percent accuracy for each of the five emotion types in both our control and experimental group by taking the number of correctly identified photographs per emotion and dividing them by the total number of participant responses for that emotion (n=30). We applied the same procedure for determining the percent accuracy for the experimental group as well. For each of the three age groups, the average percent accuracy (control and experimental group) was further calculated by adding up the number of correctly identified emotions, dividing them by the total number of participant responses within each group (n=50) and adjusting the value to a percent. In addition, the average reaction time (seconds) for the total control photograph as well as the experimental photograph groups were calculated. Average reaction times were also calculated based on the age group and photograph type evaluated. Univariate ANOVA with Tukey’s Post Hoc statistical tests ($\alpha \leq 0.05$) were performed for percent accuracy and RT between groups (n=6) as well as combining age groups for analyzing total population responses between combined ages of control and experimental photograph data.

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REFERENCES

1. Sackman, Ezgi. "Humans as Social Primates." Encyclopedia of Evolutionary Psychological Science, *Springer Nature Switzerland,* 2019, pp. 1-3. https://doi.org/10.1007/978-3-319-16999-6_1373-1.
2. Young, S. N. "The neurobiology of human social behavior: an important but neglected topic." *Journal of Psychiatry & Neuroscience,* vol. 33, no. 5, Sep. 2008, pp. 391-392.
3. Darwin, C. and Griffith, T. "The Descent of Man." vol. 4, Prometheus Books, 1874.
4. Ludwig, R.J. and Welch, M. G. "Darwin's other dilemmas and the theoretical roots of emotional connection." *Journal of Frontiers in Psychology,* vol. 10, no. 683, Apr. 2019, pp. 1-24. https://doi.org/10.3389/fpsyg.2019.00683.
5. Mehrabian, A. "Nonverbal communication." Aldine Transaction, 1972, pp. 1-17.
6. McGlynn, T. P. "How does social behavior evolve?" *Nature Education Knowledge,* vol. 3, no. 10, 2010, p. 69.
7. "The truth about reading body language." Popular Science. popsci.com/story/science/body-language-analysis/. Accessed 27 Mar. 2024.
8. Tipper, C.M., *et al.* "Body language in the brain: constructing meaning from expressive movement." *Frontiers in Human Neuroscience,* vol. 9, no. 450 Aug. 2015. https://doi.org/10.3389/fnhum.2015.00450.
9. Pietromonaco, P.R. and Collins, N.L. "Interpersonal mechanisms linking close relationships to health." *American Psychology,* vol. 72, no. 6, Sept. 2017, pp. 531-542. https://doi.org/10.1037/amp0000129.
10. Adolphia, R. "Social cognition and the human brain." *Trends in Cognitive Science,* vol. 3, no. 12, Dec. 1999, pp. 469-479. https://doi.org/10.1016/S1364-6613(99)01399-6.
11. "The Importance of Effective Communication." Northeastern University, College of Business Administration. ysrinfo.wordpress.com/wp-content/uploads/2012/06/effectivecommunication5.pdf. Accessed 1 Apr. 2024.
12. Eisenbarth, H. and Alpers, G. W. "Happy mouth and sad eyes: scanning emotional facial expressions." *Emotion,* vol. 11, no. 4, 2011, pp. 860-865.
13. Schroeder, Bradford L. "Eyes, eyebrows and their effect on the facial perception of hostility." *Modern Psychological Studies,* vol. 16, no. 2, 2011, pp. 26-38.
14. "Anatomy, head and neck; frontalis muscle." National Library of Medicine. ncbi.nlm.nih.gov/books/NBK557752/. Accessed 31 Mar. 2024.
15. Saitovitch, A., *et. al.* "Neural and behavioral signature of human social perception." *Scientific Reports,* vol. 9, no.9252, Jun. 2019, https://doi.org/10.1038/s41598-019-44977-8.
16. Eack, Shaun M. "Misinterpretation of facial expressions of emotion in verbal adults with autism spectrum disorder." *Autism,* vol. 19, no. 3, Apr. 2015, pp. 308-315. https://doi.org/10.1177/1362361314520755.
17. Wells, A. E., *et. al.* "Children with behavioral problems misinterpret the emotions and intentions of others." *Journal of Abnormal Psychology,* vol. 48, no. 2, Feb. 2020, pp.213-221. https://doi.org/10.1007/s10802-019-00594-7.
18. Emmorey, K and McCullough, S. "The bimodal bilingual brain: effects of sign language experience." *Brain and Language,* vol. 109, no. 2-3, May-Jun 2009, pp. 124-132. https://doi.org/10.1016/j.bandl.2008.03.005.
19. Koukaras, Paraskevas, *et al.* "Social media types: introducing a data driven taxonomy." *Computing,* vol. 102, no. 3, Jul. 2019, pp. 295-340. https://doi.org/10.1007/s00607-019-00739-y.
20. "The Common Sense Census: Plugged-in Parents of Tweens and Teens." *Common Sense Media.* commonsensemedia.org/sites/default/files/research/report/common-sense-parent-census_whitepaper_new-for-web.pdf. Accessed 15 Apr. 2024.
21. Giedd, J. N. "The digital revolution and adolescent brain evolution." *Journal of Adolescent Health,* vol. 51, no. 2, Aug. 2012, pp. 101-105, https://doi.org/10.1016/j.jadohealth.2012.06.002.
22. Pavlova, Marina A. "Editorial: impact of face covering on social cognition and interaction." *Frontiers in Neuroscience,* vol. 17, Feb. 2023. p.1150604, https://doi.org/10.3389/fnins.2023.1150604.
23. Nour, M., *et. al.* "Effect of face masks on interpersonal communication during the covid-19 pandemic." *Frontiers in Public Health,* vol. 8, Dec. 2020, p. 582191. https://doi.org/10.3389/fpubh.2020.582191.
24. Spiekerman, Allie M., *et al.* "Adolescents' online connections with friends driving (COVID-19): An assessment of the forms of communication and their association with emotional adjustment." *Children,* vol. 10, no. 8, Jul. 2023, p. 1281. https://doi.org/10.3390/children10081281.
25. Branje, S. and Morris, A. "The impact of the COVID-19 pandemic on adolescent emotional, social, and academic adjustment." *Journal of Research on Adolescence,* vol. 31, no. 3, Aug. 2021, p. 12668. https://doi.org/10.1111/jora.12668.
26. Barrick, Elyssa M., *et al.* "Mask exposure during COVID-19 changes emotional face processing." PLOS ONE, vol. 16, no. 10, Oct. 2021, p. e0258470. https://doi.org/10.1371/journal.pone.0258470.
27. Sadr, Javid., *et al.* "The role of eyebrows in facial recognition." Perception, vol. 32, no. 3, Mar. 2003, p. 5027. https://doi.org/10.1068/p5027.
28. Lobmaier, Janek S. and Knoch, Daria. "Face masks have a limited effect on the feeling of being looked at." *Frontiers in Neuroscience,* vol. 16, Nov. 2022, p. 1028915. https://doi.org/10.3389/fnins.2022.1028915.
29. "Common Sense census: Media use by tweens and teens." *Common Sense.* commonsensemedia.org/sites/default/files/research/report/8-18-census-integrated-report-final-web_0.pdf. Accessed 15 Apr. 2024.
30. "Teens Are Over Face-to-Face Communication Study Says." Time. time.com/5390435/teen-social-media-usage/. Accessed 19 Apr. 2024.
31. Weir, Kirsten. "Social media brings benefits and risks to teens. Psychology can help identify a path forward." *American Psychological Association,* vol. 54, no. 6, Sep. 2023, p. 46.
32. Hamilton, J. L., *et. al.* "Re-examining adolescent social media use and socioemotional well-being through the lens of the COVID-19 pandemic: A theoretical review and directions for future research." *Perspective Psychological Science,* vol. 17, no. 3, May 2022, pp. 662-679. https://doi.org/10.1177/17456916211014189.

https://doi.org/10.59720/24-120

33. Wingenbach, T., *et al.* “Sex differences in facial emotion recognition across varying expression intensity levels from videos.” PLoS One, vol. 13, no. 1, Jan. 2013, p. e0190634. https://doi.org/10.1371/journal.pone.0190634.