Sighted People Recognizing Emotions in Facial Expression Images of People With Visual Disabilities Via Cyberspace

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ABSTRACT

As technology advances today, there are many opportunities for people to communicate in cyberspace (e.g., videoconferencing) regardless of visual ability/disability. People share various information including facial expressions that are considered essential for social interaction. Despite the importance of facial expressions in conveying emotions, there is limited knowledge on how sighted people perceive the emotions of people with visual disabilities from their facial expressions online. To address the knowledge gap, this study showed sighted participants facial expression images of people with visual disabilities via Zoom and asked them to report the emotion they perceived for each image. Afterward, participants were educated about the facial modeling from a previous study and shown another set of facial expression images of people with visual disabilities. Participants were asked to report the emotion they perceived in each image. This study found many cases of incongruently perceived emotions, in which participants perceived emotions differently from the facially expressed emotions of people with visual disabilities. Yet, after education, participants were more likely to congruently perceive emotions. The research findings would be beneficial to many stakeholders in the domain of inclusive communication for everyone in cyberspace.

KEYWORDS

Online; non-verbal communication; emotional ergonomics; visual impairment; blindness

1. Introduction

Communication is the process of sharing information between two or more people. Facial expressions are a source of non-verbal information that helps people promote social interaction (Kunz et al., 2012). Facial muscles can make more than 40 facial actions, which are used individually or in combination to produce various facial expressions (Kitada et al., 2013). When people naturally express their emotions, it is considered spontaneous. When people are instructed to purposely express their emotion, it is considered voluntary (Kang et al., 2019). There are a variety of channels people can use to express their emotional states, such as non-verbal vocalizations, prosody, chemosensory signals, and language; yet, facial expressions play a critical role in conveying information about emotional states to others (Valente et al., 2018). Ekman (1999) argued that among various emotions, six basic emotions—*happiness, sadness, anger, fear, surprise, and disgust*—are innate and shared by everyone through universal facial expressions. The universality of six basic emotions has been adopted by many scholars (Matsumoto, 1992; Prkachin, 1992; Reyes et al., 2019; Waller et al., 2008; Yeasin et al., 2006).

Facial expressions can be analyzed with the Facial Action Coding System (FACS). The FACS is considered the most widely accepted and comprehensive method to examine visually discernible facial muscle movements for emotions (Ekman & Friesen, 1976, 1978). It breaks down facial expressions into individual components of facial muscle movements, called Action Units (AUs). AUs cover various facial components, such as eyelids, lips, and brows (Tian et al., 2002). AUs are mapped onto facial expressions of emotions, e.g., AU 4 refers to Brow Lowerer, AU 5 refers to Upper Lid Raiser, and AU 12 refers to Lip Corner Puller. For example, Cordaro (2014) used the FACS to analyze various facial expressions of sighted people, e.g., AU $4+5+17+23+24$ for Anger; AU $7+9+19+25+26$ for Disgust; AU $1+2+4+5+7+20+25$ for Fear; AU $6+7+12+25+26$ for Happiness; AU $1+4+6+15+17$ for Sadness; and AU $1+2+5+25+26$ for Surprise. Kim (2023a) also used the FACS to analyze facial expressions of people with visual disabilities, e.g., AU $4+15+44$ for Anger; AU 4 for Disgust; AU $1+5+25$ for fear; AU $6+12+25$ for Happiness; AU $17+41+54+64$ for Sadness; and AU $1+5+25+27$ for Surprise.

It is essential for people to be equipped with not only the ability to express their emotions but also the ability to perceive others' emotions to facilitate social interaction (Gao et al., 2013). Learning can affect how people recognize emotions through facial expressions (Barrett et al., 2019). Even infants can learn, imitate, and discriminate among facial expressions by observing other people making facial expressions (Field et al., 1982). Ekman et al. (1969) suggested that universal expressions could be formed by culture-constant learning, e.g., people see, understand, and mimic facial

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expressions. However, people with visual disabilities are less likely to have opportunities to observe and learn facial expressions posed by others due to their vision loss. Hence, it is anticipated that those with and without visual disabilities may have different mental models in understanding, expressing, or perceiving facially expressed emotions. Given the logic, when people with visual disabilities communicate with sighted people, their facially expressed emotions may be incongruently recognized by sighted people. On the other hand, a systematic literature review by Valente et al. (2018) argued that prior visual experience in life does not affect people making "spontaneous" facial expressions; however, it affects "voluntary" facial expressions. This suggests that people with visual disabilities may have different voluntary facial expressions from their sighted peers. Other research has found similar results. For example, several researchers (Galati et al., 2001; 2003; Matsumoto & Willingham, 2009; Tracy & Matsumoto, 2008) found no significant difference in "spontaneous" facial expressions between people with and without visual disabilities. Galati et al. (1997) found a significant difference in "voluntary" facial expressions between the two groups. Yet, little is known about how sighted people interpret voluntary facial expressions of people with visual disabilities via cyberspace.

As technology advances today, people are likely to have many opportunities to interact with others online by sharing facial expressions. There have been research efforts to obtain a deep understanding of facial expressions in cyberspace, which will benefit many stakeholders in a variety of fields, including healthcare, social media, e-commerce, and education. For example, emotional interactions between clinicians and patients were found to be critical for the quality of healthcare service in computer-mediated psychotherapy (Alvandi et al., 2019). Facial expressions that were collected online were analyzed to detect Parkinson's disease (Ali et al., 2021) and to predict the personality of online users (Biel et al., 2012). Real-time facial expression analysis was also studied to facilitate communication between online users (Chandrasiri et al., 2004). Facial expressions of e-commerce customers were examined to develop an online recommendation system that acts as a shopping advisor (Bandyopadhyay et al., 2022). The satisfaction of online museum visitors was measured by analyzing their facial expressions (Nubani & Öztürk, 2021). Many education researchers also studied the facial expressions of online students to promote student engagement in distance learning (Savchenko et al., 2022; Wang et al., 2020; Zhang et al., 2020).

However, many research studies tend to focus on sighted people. There is less research on facial expressions of people with visual disabilities in cyberspace. Ashok and John (2018) and Zhao et al. (2018) introduced a facial expression recognition system that helped those with visual disabilities to understand other persons' facial expressions in person. Den Uyl and Van Kuilenburg (2005) focused on an online facial expression recognition system, but it was set to help sighted people to read facial expressions of general populations. There are only a handful of research reports on facial expressions of people with visual disabilities in online settings, yet less attention has been paid to how sighted people interpret facial expressions of people with visual disabilities in online communication settings. For example, many engineering researchers focused on developing alternative means (e.g., wearable vibrotactile devices and smartphone camera-based emotion recognition applications) to help people with visual disabilities to better understand the facial expressions of others including sighted people (Buimer et al., 2018; Krishna et al., 2010; Panchanathan et al., 2016; Zhao et al., 2018). Another group of studies (Kim, 2023a, 2023b) examined how people with visual disabilities expressed emotions facially to others in online settings. Yet, little is known about how sighted people interpret facial expressions of people with visual disabilities in online communication settings (see Table 1).

Hence, this study aims to investigate the degree to which sighted people recognize congruently facially expressed emotions of people with visual disabilities via cyberspace. A previous study (Kim, 2023a) modeled various facial expressions of emotions posed by people with visual disabilities in online settings, such as Zoom. The results of the previous study found evidence that the facial expressions of people with visual disabilities are not the same as those of sighted people, leading to the hypothesis that sighted people might be unable to recognize congruently the facially expressed emotions of people with visual disabilities in online settings. This study will, thus, examine the hypothesis. This study will also examine the degree to which sighted people can be educated to promote emotion recognition of the facially expressed emotions of people with visual disabilities in online settings.

2. Methods

2.1. Participants

A power analysis was conducted to determine the sample size needed to effectively assess people's ability to congruently feel the facially expressed emotions of others (e.g., empathy) (Martins et al., 2019). A sample size of at least 33 participants is sufficient to detect differences in empathy among participants, with a Type I error rate of .05, a Type II error rate of 0.2, and a power of 0.8. A convenience sample of 43 participants contributed to this study. Inclusion criteria were English-speaking, 18 years old or older, and no visual impairment/blindness. Approval for this study was obtained from the Institutional Review Board (IRB). Informed consent was obtained from all participants.

2.2. Procedures

A set of 30 facial expression images (five images by six basic emotions) were randomly extracted from the previous study (Kim, 2023a) where 28 people with visual disabilities (11 male and 17 female; 58.64 ± 17.93 years old) made voluntary facial expressions of emotions via Zoom. Of the 28 people with visual disabilities, 9 had visual acuity between 20/200

Table 1. Summary of literature.

Categories	Authors	Methods	Findings
Facial expressions influenced by vision loss	(Galati et al., 2001)	Facial expressions of 10 congenitally blind children and 10 sighted children (ages ranging from 6 months to 4 years) were compared.	There were no significant differences in spontaneous facial expressions between people with and without visual disabilities.
	(Galati et al., 2003)	Facial expressions of 10 congenitally blind children and 10 sighted children (9 years and 6 months of age on average) were compared.	
	(Matsumoto & Willingham, 2009)	The facial expressions of 59 athletes with visual disabilities (congenital and non-congenital blindness) were compared with those of 51 sighted athletes.	
	(Tracy & Matsumoto, 2008)	Facial expressions of 53 athletes with visual disabilities (congenital and non-congenital blindness) from 20 nations were compared with those of 87 sighted athletes from 36 nations.	
	(Galati et al., 1997)	The facial expressions of 14 people with visual disabilities (age ranging from 16 to 69 years) were compared with those of 14 sighted people (age ranging from 20 to 70 years).	There was a significant difference in voluntary facial expressions between people with and without visual disabilities.
	(Valente et al., 2018)	A systematic literature review was conducted for 21 papers published between 1932 and 2015, focusing on the facial expressions of people with blindness.	Prior visual experience in life did not affect people making spontaneous facial expressions; however, it affected voluntary facial expressions.
Understanding of facial expressions of general populations in cyberspace	(Ali et al., 2021)	Facial expressions were analyzed using the Facial Action Coding System (FACS) codes. 1812 videos of 604 people (61 with Parkinson's disease and 543 without Parkinson's disease) were collected online through a web-based tool, www.parktest.net.	Facial expressions that were collected online could contribute to detecting Parkinson's disease.
	(Biel et al., 2012)	Facial expressions were collected from YouTube vloggers ($n = 281$) expressing various facial expressions. Annotators watched the videos and categorized vloggers by five emotional traits (extroversion, agreeableness, conscientiousness, emotional stability, and openness to experience).	Facial expressions were helpful in predicting the personality of online users.
	(Chandrasiri et al., 2004)	Researchers developed a system equipped with three modules: (1) a real-time facial expression analysis module, (2) an affective 3D agent module with facial expression synthesis and text-to-speech technology, and (3) a communication module.	A real-time facial expression analysis was employed to facilitate the communication between online users.
	(Bandyopadhyay et al., 2022)	Online recommendation systems in e-commerce typically require a large dataset (e.g., purchase history) to predict and provide adequate recommendations for e-commerce customers. To address the limitation, researchers developed a system where customers' facial expressions were analyzed in real time to detect emotions and help to select products that fit customers' needs.	Facial expressions of e-commerce customers were useful in developing an online recommendation system as a shopping advisor.
	(Nubani & Öztürk, 2021)	Over 2000 facial expressions were captured from online museum visitors. The satisfaction of online museum visitors was measured by analyzing their facial expressions.	The research findings (facial expressions of online visitors) suggested that experiencing online museums was as engaging as experiencing museums in person.
	(Savchenko et al., 2022)	Student facial expressions in e-learning settings were analyzed to predict the level of virtual students' engagement.	The proposed algorithms could detect the emotions of virtual students in real time. The algorithms were suggested to be used for real-time video processing even on a mobile device of students.
	(Wang et al., 2020)	Facial expressions of 27 online students were collected via a camera and analyzed using facial expression recognition algorithms.	The proposed algorithms were found to be effective in detecting and recognizing the emotions of online students.
	(Zhang et al., 2020)	Online students' behavior data (facial expressions and a computer mouse's movements) were analyzed to measure the level of students' engagement online.	It was found that the user behavior data (mouse usage and facial expressions) were useful in examining the level of students' engagement online.
	(Den Uyl & Van Kuilenburg, 2005)	A FaceReader application was developed using the Active Appearance Model, AAM. It could classify facial expressions (happiness, anger, sadness, surprise, disgust, and neutral) with an accuracy of 89%.	An online facial expression recognition system was introduced but it was limited to helping sighted people to read facial expressions of general populations.
Understanding of facial expressions of people	(Kim, 2023a, 2023b)	People with visual disabilities expressed facial emotions via Zoom, which included anger,	Facial expression modeling was performed for various emotions of people with visual

(*continued*)

Table 1. Continued.

Categories	Authors	Methods	Findings
with visual disabilities online		fear, disgust, happiness, surprise, neutrality, calmness, and sadness. The facial expressions were analyzed using the FACS that encodes the movement of specific facial muscles called Action Units (AUs).	disabilities in cyberspace such as Zoom. Despite that, little is known about how sighted people perceive and interpret the facial expressions of people with visual disabilities in online communication settings.
Assistive technology for people with visual disabilities to read facial expressions in others in person	(Ashok & John, 2018)	A convolution neural network (CNN) was used to train emotion recognition models, which were implemented in a Raspberry Pi computer. People with visual disabilities use a computer equipped with a camera to read facial expressions and use headphones to be verbally informed of facial emotions.	A facial expression recognition system was introduced to help people with visual disabilities to read other persons' facial expressions in person.
	(Buimer et al., 2018)	Assistive technology (a wearable vibrotactile device with a head-mounted camera) was developed to help people with visual disabilities to read facial expressions in others in person.	Many engineering researchers focused on developing alternative means (e.g., wearable vibrotactile devices and smartphone camera-based emotion recognition applications) to help people with visual disabilities to better recognize facially expressed emotions of others including sighted people.
	(Krishna et al., 2010)	Vibrotactors, mounted on the back of a glove, were developed for people with visual disabilities to feel haptic emoticons that represent six basic emotions.	
	(Panchanathan et al., 2016)	A social interaction assistant system was developed for people with visual disabilities using eyeglasses with a small camera. The incoming video data were analyzed using machine learning and computer vision algorithms. People with visual disabilities were informed of facially expressed emotions via a haptic belt.	
Assistive technology for people with visual disabilities to read facial expressions in others via online	(Zhao et al., 2018)	An accessibility bot was developed to help people with visual disabilities recognize the faces of friends and facial expressions online.	A facial expression recognition system was introduced to help people with visual disabilities to read other persons' facial expressions via Facebook Messenger.

and 20/400, 4 had visual acuity between 20/400 and 20/1200, 13 had visual acuity less than 20/1200, and 2 had blindness with no light perception at all. This study was also conducted via Zoom. Participants were shown the facial expression images in a random order. Participants were allowed to see the images as long as they wanted. After seeing each image, participants reported which emotion they perceived. Participants were then instructed in the FACS system and the previous study's results, i.e., FACS-based models accounting for facial expressions of six basic emotions in people with visual disabilities. Afterward, another set of 30 facial expression images was also extracted from the previous study, and participants were shown the images in random order. After seeing each image, participants reported which emotion they perceived. Thus, each participant was shown a total of 60 images to assess their ability to perceive emotions congruently in response to the given facially expressed emotions of people with visual disabilities. Too many stimuli would negatively affect participants' cognitive activity, leading to poor performance in seeing, decoding, and recognizing facially expressed emotions. Each participant's task lasted approximately 50–60 min, which is the time when attention begins to wane (Marley & Tougaw, 2018; Ramstetter et al., 2010).

2.3. Data analysis

Statistical analyses were performed using the IBM SPSS Statistics for Macintosh, version 24 (IBM Corp., 2016). Chi-square testing was conducted to examine if there was a significant difference in the type of perceived emotions before and after education. The composition (%) of perceived emotions for each facially expressed emotion was examined.

3. Results

Chi-square testing (see Table 2) found significant differences in perceived emotions before and after education in response to the given facial images of emotions (anger, disgust, fear, surprise, happiness, and sadness).

3.1. Angry facial images

Before education, anger was the least perceived emotion. The most perceived emotion was happiness, followed by surprise. After education, anger was the most perceived emotion; happiness was not perceived at all; and surprise was significantly less perceived.

3.2. Disgust facial images

Before education, sadness was the most perceived emotion, followed by disgust. After education, sadness was significantly less perceived, while disgust became the most perceived emotion.

Table 2. Composition (%) of perceived emotions, given the facial expressions of the six basic emotions.

Perceived emotions	Image of *angry* facial expression: Before education	Image of *angry* facial expression: After education	χ^2 test before and after	Image of *disgust* facial expression: Before education	Image of *disgust* facial expression: After education	χ^2 test before and after	Image of *fear* facial expression: Before education	Image of *fear* facial expression: After education	χ^2 test before and after
Anger	9.3	58.7	$\chi^2(1) = 75.11, p < 0.001, v = .23$	15.89	30.84	$\chi^2(1) = 10.24, p < 0.001, v = .10$	9.35	2.82	$\chi^2(1) = 7.54, p = 0.006, v = .17$
Disgust	13.5	21.1	$\chi^2(1) = 3.46, p = 0.063, v = .07$	21.96	38.79	$\chi^2(1) = 9.97, p = 0.002, v = .09$	19.16	1.88	$\chi^2(1) = 30.42, p < 0.001, v = .26$
Fear	9.8	6.1	$\chi^2(1) = 1.88, p = 0.17, v = .07$	12.15	3.27	$\chi^2(1) = 10.94, p < 0.001, v = .18$	13.55	28.17	$\chi^2(1) = 10.80, p = 0.001, v = .11$
Surprise	15.8	2.8	$\chi^2(1) = 19.60, p < 0.001, v = .22$	12.15	5.14	$\chi^2(1) = 6.08, p < 0.014, v = .13$	13.08	61.5	$\chi^2(1) = 66.72, p < 0.001, v = .20$
Happiness	40	0	N/A	10.28	10.28	$\chi^2(1) = .00, p = 1.00, v = .00$	23.83	0	N/A
Sadness	11.6	11.3	$\chi^2(1) = .02, p = 0.87, v = .01$	27.57	11.68	$\chi^2(1) = 13.76, p < 0.001, v = .19$	21.03	5.63	$\chi^2(1) = 19.11, p < 0.001, v = .18$
χ^2 test before and after	$\chi^2(5) = 186.99$, $p < 0.001, v = .661$			$\chi^2(5) = 50.99$, $p < 0.001, v = .345$			$\chi^2(5) = 183.88$, $p < 0.001, v = .66$		

Perceived emotions	Image of *surprise* facial expression: Before education	Image of *surprise* facial expression: After education	χ^2 test before and after	Image of *happy* facial expression: Before education	Image of *happy* facial expression: After education	χ^2 test before and after	Image of *sad* facial expression: Before education	Image of *sad* facial expression: After education	χ^2 test before and after
Anger	1.86	2.33	$\chi^2(1) = 0.11, p = 0.739, v = .03$	2.33	0.47	$\chi^2(1) = 2.67, p = 0.102, v = .21$	16.36	7.48	$\chi^2(1) = 7.08, p = 0.008, v = .12$
Disgust	7.44	2.33	$\chi^2(1) = 5.76, p = 0.016, v = .17$	6.05	0.93	$\chi^2(1) = 8.07, p = 0.005, v = .23$	22.9	17.76	$\chi^2(1) = 1.39, p = 0.238, v = .04$
Fear	7.91	13.02	$\chi^2(1) = 2.69, p = 0.101, v = .08$	6.98	1.87	$\chi^2(1) = 6.37, p = 0.012, v = .18$	6.54	2.8	$\chi^2(1) = 3.20, p = 0.074, v = .13$
Surprise	10.23	77.21	$\chi^2(1) = 110.30, p < 0.001, v = .24$	10.23	7.94	$\chi^2(1) = 0.64, p = 0.42, v = .04$	15.42	1.4	$\chi^2(1) = 25.00, p < 0.001, v = .26$
Happiness	66.05	0.93	$\chi^2(1) = 136.11, p < 0.001, v = .31$	67.44	88.79	$\chi^2(1) = 6.05, p = 0.014, v = .04$	17.76	1.4	$\chi^2(1) = 29.88, p < 0.001, v = .27$
Sadness	6.51	4.19	$\chi^2(1) = 1.09, p = 0.297, v = .07$	6.98	0	N/A	21.03	69.16	$\chi^2(1) = 54.97, p < 0.001, v = .17$
χ^2 test before and after	χ^2 (5) = 256.06, $p < 0.001, v = .772$			$\chi^2(5) = 38.79$, $p < 0.001, v = .301$			$\chi^2(5) = 121.52$, $p < 0.001, v = .533$		

3.3. *Fear facial images*

Before education, happiness was the most perceived emotion, followed by sadness, disgust, and fear. After education, surprise became the most perceived emotion, followed by fear, while all the other emotions were significantly less perceived.

3.4. *Surprise facial images*

Before education, happiness was the most perceived emotion, followed by surprise. After education, surprise became the most perceived emotion, followed by fear, while happiness was the least perceived emotion.

3.5. *Happy facial images*

Before education, happiness was the most perceived emotion was happiness. After education, happiness was still the most perceived emotion, while all the other emotions were less perceived.

3.6. *Sad facial images*

Before education, disgust was the most perceived emotion, followed by sadness. After education, sadness was the most perceived emotion, while the other emotions were less perceived.

4. Discussion

Prior studies focused on how sighted people perceive emotions in facial expressions of other sighted people (Den Uyl & Van Kuilenburg, 2005); how people with visual disabilities express emotions facially (Kim, 2023a, 2023b); and how researchers develop assistive technologies to help people with visual disabilities perceive emotions in others (Ashok & John, 2018; Zhao et al., 2018). This study contributes to addressing the knowledge gap of how sighted people perceive emotions in the facial expressions of people with visual disabilities, especially via cyberspace. As summarized in Table 3, this study found many incongruent cases where sighted participants perceived emotions differently than the emotions facially expressed by people with visual disabilities online. Such incongruent emotions could lead to poor communication outcomes (e.g., lack of empathy) betwen people with and without visual disabilities.

This study also contributes to a deep understanding of the degree to which sighted people could enhance their ability to congruently recognize facially expressed emotions of people with visual disabilities online via education. Education was found to be helpful in improving sighted people's ability to congruently perceive the emotions of people with visual disabilities online, but the effectiveness of education varied depending on the emotion. The detailed discussions follow below.

Table 3. The most perceived emotions between before and after education.

Given facially expressed emotions	The most perceived emotion: Before education	After education
Anger	Happiness	Anger
Disgust	Sadness	Disgust
Fear	Happiness	Surprise
Surprise	Happiness	Surprise
Happiness	Happiness	Happiness
Sadness	Disgust	Sadness

4.1. Before education—anger, fear, surprise vs. happiness

Before education, many incongruent cases were observed between facially expressed emotions and perceived emotions. For example, the facial expressions of *anger, fear,* and *surprise* tended to be perceived as happiness. According to the modeling from the previous study (Kim, 2023a), angry facial expressions were presented with AU 4 + 14 (brow lower + dimpler), AU 4 + 15 + 44 (brow lowerer + lip corner depressor + squint), and a neutral expression. Yet, those facial muscle movements were not distinctively large in expressing anger and fear. Without paying close attention, observers are less likely to recognize those facial cues. The experiment in this study was designed to ask participants to see a large number of facial images in a row, which may have led them to more focus on quickly scanning the given images and choosing an emotion. Thus, they might have not spent sufficient time examining facial expression cues in detail. However, the amount of time used was typical of what people use to recognize emotions via facial expressions in daily life. For example, Schyns et al. (2009) revealed that the human brain took only 200 milliseconds to gather most of the information from a facial expression to perceive emotion. Martinez and Du (2010) found that happiness was the fastest emotion to be perceived (23–28 ms), followed by neutral, disgust, surprise, and fear (three to four times longer than happiness), and sadness and anger (10 times longer than happiness, which is still less than 280 ms).

Based on the finding that many of the given facially expressed emotions (anger, fear, and surprise) were incongruently perceived, it could hypothetically be argued that sighted people have a lack of the ability to congruently recognize facially expressed emotions of people with visual disabilities. Kim (2023a) also shared a similar view that sighted people would find it difficult to distinguish facially expressed emotions of people with visual disabilities, especially between facial expressions of high-arousal negative emotions (e.g., anger and fear) and those of high-arousal positive emotions (e.g., happiness). People with visual disabilities used the orbicularis oculi muscles (i.e., eye-related facial muscles) more frequently in expressing negative emotions (anger) than positive emotions (happiness) (Kim, 2023a). Similar results were also found in sighted people, e.g., eyes-related facial muscles were more often engaged in expressing negative emotions, while lips-related facial muscles (e.g., zygomaticus major muscle) were more often engaged in expressing positive emotions (Dimberg et al., 2000; McDaniel et al., 2007; Vail et al., 2016). Thus, it is recommended that an education program be designed to guide sighted people on how to pay more attention to subtle facial cues, e.g., eye-related facial muscle movements for negative emotions and lips-related facial muscle movements for positive emotions. In contrast to anger and fear, surprise is a complex emotion that can be both *positive* (induced by "pleasant" events) and *negative* (induced by "unpleasant" events) (Zhu et al., 2019). Participants in this study might have considered the given surprise facial expressions as *positive* surprise, which might have led them to perceive happiness instead of surprise.

4.2. Before education—disgust vs. sadness

Before education, the facial expressions of *disgust* were likely perceived as sadness, while the facial expressions of *sadness* were likely perceived as disgust. The common AU shared between *disgust* and *sadness* was a neutral expression although each facial expression included distinctive AUs, e.g., AU 4 (brow lowerer) for disgust and AU 17 + 41 + 54 + 64 (chin raiser + lid droop + head down + eyes down) for sadness. Participants might have missed those facial cues, leading to confusion and incongruent emotion perception. A similar research finding was also reported in the literature. For example, Widen and Russell (2010) investigated how well children and adults could recognize facial expressions of disgust among other emotions (including sadness). They found that none of the adults recognized the disgusted facial expressions as sadness, while the children did. Children, compared to adults, might have fewer opportunities to learn, adopt, and imitate the facial expressions of others, leading to different mental models of facial expressions for fear and sadness, resulting in the difference in understanding those facial expressions. In the same logic, as compared to people with visual disabilities, sighted participants in this study might also have different mental models of facial expressions for disgust and sadness, causing confusion when they encountered the disgust and sad facial expressions posed by people with visual disabilities. There is a need to design an education program for sighted people to pay more attention to such distinctive AUs between disgust and sadness.

4.3. After education—fear

After education, the ability to recognize facially expressed emotions was improved. Sighted participants perceived the emotions of anger, disgust, surprise, happiness, and sadness congruently, except for fear. The fearful facial expressions were likely perceived as a surprise. The fearful facial expressions included AU 1 + 5 + 25 (inner brow raiser + upper lid raiser + lips part), which are also part of the surprised facial expressions. The surprised facial expressions included AU 1 + 5 + 25 + 27 (mouth stretch) and AU 25 + 45 (blink). As the facial expressions were presented as images, sighted participants might have been unable to notice such dynamic facial muscle movements as AU 27 and AU 45. Thus, this might have led them to perceive the fearful facial expressions as surprise.

Similar research findings are also reported in the literature. In general, fearful expressions display *shock* in response to negative events (e.g., frightening situations, signaling a potential threat), while surprised facial expressions acknowledge unexpected events (e.g., either positive or negative situations) (Duan et al., 2010; Schroeder et al., 2004). Surprise is largely expressed through raised inner/outer brows, raised upper eyelids, and an open mouth, while fear is significantly expressed through lowered brows and lip stretching (Ekman, 1993). Yet, it is well documented that people are likely to be confused by facial expressions of fear and surprise because both emotions share similar facial features, such as a wide-eyed face (Zhao et al., 2013, 2017). This study also provides evidence that such confusion is likely observed in sighted participants reading fearful and surprised facial expressions of people with visual disabilities. There is a need to design an education program to help sighted people pay more attention to such facial cues as mouth stretching and blinking in order to differentiate between fear and surprise in people with visual disabilities.

4.4. Limitations

This study might have been affected by a few limitations. Participants were shown the images of full-frontal faces, but in the real world, people often see each other in more natural contexts, such as seeing the side view of a person (*face profiles*). If face profiles were employed in the experiments, this study might have yielded different results. This study examined the six basic emotions (anger, disgust, fear, surprise, happiness, sadness), but only one emotion (happiness) was positive. Different results might have been found if this study considered diverse positive emotions, such as joy, gratitude, pride, serenity, and inspiration (Campos et al., 2013). Future research with a larger sample size will address these limitations.

4.5. Conclusion

This study contributed to advancing knowledge about the ability of sighted people to recognize facially expressed emotions of people with visual disabilities via cyberspace. Many incongruent results were found between facially expressed emotions and perceived emotions. Sighted participants were not competent in recognizing the emotions of people with visual disabilities as they tended to miss critical, but subtle facial cues. After being educated, more congruent results were observed except for fearful facial expressions. Dynamic facial muscle movements are considered important for congruently recognizing emotions of people with visual disabilities. Future research will use videos of facial expressions to better educate people how to understand the facial expressions of people with visual disabilities online. The acquired results will contribute to developing artificial intelligent software that can recognize the facial expressions of people with visual disabilities.

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The authors report there are no competing interests to declare.

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