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Individual differences in spontaneous facial expressions in people with visual impairment and blindness

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Abstract
People can visualize their spontaneous and voluntary emotions via facial expressions, which play a critical role in social interactions. However, less is known about mechanisms of spontaneous emotion expressions, especially in adults with visual impairment and blindness. Nineteen adults with visual impairment and blindness participated in interviews where the spontaneous facial expressions were observed and analyzed via the Facial Action Coding System (FACS). We found a set of Action Units, primarily engaged in expressing the spontaneous emotions, which were likely to be affected by participants' different characteristics. The results of this study could serve as evidence to suggest that adults with visual impairment and blindness show individual differences in spontaneous facial expressions of emotions.

Keywords
Blindness, emotion, individual differences, spontaneous facial expression, visual impairment

Introduction

People use facial expressions to show his or her emotional states (e.g., happy and surprised) via a variety of small muscle (micromotor) movements in the face (Harley, 2016). Facial expressions play an important role in communication (McCarthy & Warrington, 1990). They convey a number of messages in a range of contexts (Elliott & Jacobs, 2013). From a theoretical point of view, facial expressions were essential for ancestors to gather information about surroundings to increase the chances of survival (Darwin, 1872). For example, humans lift the eyebrows to quickly respond to unexpected environmental events (e.g., fearful and dangerous events) because such facial muscle movements would help them to widen the visual field to see more and obtain further information, contributing to logical reasoning. Although such instrumental functions may have been weakened (or disappeared), the facial expressions still exist in humans, that is, humans' biological endowment (Elliott & Jacobs, 2013).

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A well-known researcher, Ekman (1992) argued that humans use a set of facial expressions that are innate and culturally acceptable—for example, people raise their eyebrows to express that they feel surprised. The facial musculature has the capability of generating over 40 independent actions, which would theoretically lead to the potential to show an extremely large set of facial expressions (Valente et al., 2018). Despite such a large potential repertoire, Ekman (1993) claimed that humans tend to produce spontaneously a small number of facial configurations (e.g., joy, sadness, fear, anger, and so on). Yet, Ekman (1999) also acknowledged that there were opposite arguments leading to the challenges of claiming that facial expressions are universal. One of the challenges was related with the contention that all the research participants were those who had the opportunity to learn these expressions from each other or from a common source (e.g., TV shows). Thus, if research participants were individuals who were visually isolated, they might display completely different facial expressions.

Previous studies indicated that there was a relationship between emotional expressions and sociodemographic factors. For example, Iakimova et al. (2016) found that age negatively affected anger and neutrality recognition, while education level positively did so. Soussignan et al. (2013) compared gender effects on facial mimicry. People often display changes in their own facial expressions when they encounter another person's emotional expressions, which is referred to as facial mimicry. Their study found that women showed less anger mimicry with corrugator muscles (i.e., a small, narrow, pyramidal muscle close to the eye) but showed more sadness mimicry with depressor anguli oris muscles (i.e., a facial muscle associated with frowning). Dimberg and Lundquist (1990) observed that women reacted stronger with zygomaticus major muscles (i.e., a thin paired facial muscle that extends diagonally from the cheekbone to the angle of the mouth) and zygomaticus minor muscles (i.e., a thin paired facial muscle extending horizontally over the cheeks) as compared with men when they were exposed to happy facial expressions of others. Brand and Ulrich (2019) found that people who did not perform physical exercise regularly tended to initiate negative facial expressions on exercise-related stimuli significantly faster than those who did so. White et al. (2019) found that low socioeconomic status impacts the processing of emotional facial expressions. Individuals from a low-income family background showed an increased responsiveness to angry faces within the amygdala (i.e., gray matter inside each cerebral hemisphere, involved with the experiencing of emotions). They argued that low socioeconomic status is closely related with greater exposure to uncontrollable stressors, possibly leading to individual differences with regard to emotional information processing (e.g., emotional perception and reaction).

Facial expressions can be categorized in either voluntary or involuntary (spontaneous) facial expressions. The voluntary and spontaneous facial expressions show opposite characteristics. In contrast to spontaneous facial expressions, voluntary facial expressions are, for example, intentionally generated and socially learned through human communication; thus, they can be employed to hide underlying intentions and feelings (Gola et al., 2017). There are many research studies on emotional expressions taking advantage of professional actors' facial expressions (Carroll & Russell, 1997; Krumhuber & Scherer, 2011; Scherer & Ellgring, 2007). However, it is argued that actors' expressions are considered as voluntary expressions that are set to convey messages via intentional and strategic manipulation, which is different from spontaneous expressions (Namba et al., 2017). Spontaneous expressions differ from voluntary expressions in terms of morphology and dynamics, including velocity and smoothness of motion (Hager & Ekman, 1985). Facial mimicry often occurs spontaneously and promptly within one second after the stimulus onset (Dimberg, 1982; Dimberg et al., 2000). People tend to respond instantly with facial expressions during social interactions, for example, people smile when they encounter other people who look happy (Kaiser et al., 2017). Even newborn infants can make spontaneous facial expressions (Field et al., 1982).

However, little is known about mechanisms of emotion that account for spontaneous facial expressions as compared with voluntary facial expressions, especially among people with visual impairment and blindness. The systematic literature reviews by Valente et al. (2018) indicated that there have been merely a handful of research studies investigating facial expressions in people with visual impairment and blindness. Furthermore, there has been less attention paid to individual differences in people who share the same disability category, *visual disability*. In addition, many prior studies were merely conducted with a small sample of participants with visual disabilities (Chiesa et al., 2015; Cole et al., 1989; Freedman, 1964; Galati et al., 2001; Gao et al., 2013; Iverson & Goldin-Meadow, 1997; McDaniel et al., 2019; Webb, 1977; Zhao et al., 2018) and focused on children with visual disabilities over adults with visual disabilities (Ellis et al., 1987; Fraiberg, 1975; Fulcher, 1942; Galati et al., 2003; Ghosh, 2014; Goodenough, 1932; Iverson & Goldin-Meadow, 1997, 1998; Thompson, 1941; Webb, 1977). To address the knowledge gap, this study focuses on individual differences in adults with visual disabilities showing spontaneous facial expressions of emotions.

Methods

Participants

Participants were English speaking, 18 years old or older, and poor visual acuity. Participants with visual acuity between 20/200 and 20/400 were considered as those with visual impairment, while participants with visual acuity less than 20/400 were considered as those with blindness (World Health Organization, 2008). Participants were recruited in collaboration with community organizations such as community centers and a public library for the blind. Approval for this study was obtained from the Institutional Review Board (IRB). A convenient sample of 30 participants were invited to Zoom interviews, but we excluded 11 participants from the data analysis because three participants encountered technical issues that failed to continue video recording; five participants who used a smartphone camera did not aim properly at their face during recording; two participants did not show changes in facial expression during the entire interview period; and one participant had difficulty in using facial muscles due to a personal health condition. Thus, our data analysis was accomplished with data obtained from 19 participants. Three participants were born with blindness (visual acuity between 20/1200 and no light perception), one participant was born with visual impairment (visual acuity poor than 20/200), and one participant lost vision at age 4. The remaining participants lost vision later ranging from 28 to 73 years of age. Characteristics of the participants were presented in the Table 1.

Procedure

This study observed the degree to which participants with visual impairment and blindness were naturally engaged in spontaneous facial expressions. It was a semi-structured interview instead of a fully structured interview. The semi-structured interview contributed to making participants feel less formal but more causal, for example, talking to friends in informal settings. Interview questions were associated with their personal experiences with vision loss, relevant challenges, and opportunities in everyday life. Participants' comments would be followed by the interviewer's questions to help participants talk in more depth about their experiences. It could, thus, contribute to increasing the opportunity for participants to make spontaneous facial expressions. Participants were informed that their facial expressions were studied for research. Yet, we made sure not to force participants to make facial expressions. We informed participants that they would not need to

Table 1. Descriptions of the participants.

Participants	$n = 19$
Visual acuity	
Between 20/200 and 20/400	6
Less than 20/400	13
Duration of visual impairment (years)	22.37 ± 18.95
Onset of visual impairment (years)[a]	
Early onset ($n = 10$)	0.80 ± 1.79
Late onset ($n = 20$)	47.57 ± 13.59
Age (years)	57.63 ± 18.99
Gender	
Male	7
Female	12
Race/ethnicity	
African American	8
European American	9
Hispanic American	1
Others	1
Occupation	
Employed	8
Unemployed	11
Exercise regularly	15
Head of household	
Living alone	7
With family, relatives, friends, or combination of them	12
Education	
High school or equivalent	5
Associate	4
Bachelor's (BA or BS)	2
Master's	7
Doctorate	1
Household income	
⩽$25,999	3
$26,000–$51,999	5
$52,000–$74,999	4
⩾$75,000	3
Declined to answer	4
Marital status	
Married	8
Not married	4
Widow(er)	3
Divorced	4

[a]Participants with early onset of vision loss had lost their sight before 11 years of age (Voss et al., 2004).

make facial expressions intentionally for us. We also did not intervene even though they made no (or lack of) facial expressions during the interview session. The interviews were video recorded for the data analysis. Each participant joined the interview (less than 60 min) via Zoom. Participants' family members were allowed to help the participant with installing or running the Zoom application. Yet, once the interview began, family members were instructed not to join the interview.

Data analysis

The Facial Action Coding System (FACS) was employed in analyzing facial expressions (Ekman & Friesen, 1978; Ekman & Friesen, 1976). The FACS enabled us to break down all visually discernible facial expressions into a set of facial muscle movements, called Action Units. The Action Units were associated with a range of facial components such as eyebrows, eyelids, lips, head, and cheeks. We considered their discussions while analyzing their facial expressions. For example, when they talked about happy moments in their life, they did smile and use relevant words such as Happy, Love, and so on. Those contextual cues helped to code their facial expressions. It is well documented that people use emotional words to convey information about their emotional states (Abbassi et al., 2015; Weis & Herbert, 2017; Wu et al., 2021). To identify emotions of the participants in this study, we, thus, relied on the emotional words they used when they made facial expressions; for example, "I am happy . . . ," "I do not understand . . . ," and "I am surprised. . ." We used the IBM SPSS Statistics for Macintosh, version 24 (IBM Corp., 2016) for statistical data analyses. An interrater reliability analysis using Cohen's kappa statistic was performed to determine consistency between two raters. There was substantial agreement among the raters as the interrater reliability was found to be $\kappa = .85$ (95% confidence interval [CI]: .59–1.12).

Results

As shown in Figure 1, a range of facial expressions were coded with the FACS Action Units to obtain a deeper understanding of spontaneous emotions perceived by adults with visual impairment and blindness. The majority of the codes accounted for the emotion of happy, such that we examined whether there was a significant difference in the type of Action Units engaged in expressing happy. A chi-square test showed that a significant difference was found in the type of Action Units, $\chi^2(137) = 211.07$, $p < .001$.

We sorted the Action Units into facial components (e.g., lips, eyebrows, eyelids, and so on) and compared them in terms of the frequency of engagement in expressing happy. The Action Units most frequently engaged in expressing happy were related to lips. As reported in Table 2, the engagement of lips is significantly greater (67 times), compared with that of other facial components such as cheeks (27 times), eyelids (13 times), eyebrows (21 times), and head (8 times).

We also compared the "combination" of Action Units that were engaged in expressing happy. A chi-square test showed that a significant difference was found in the combination of Action Units, $\chi^2(20) = 40.76$, $p = .004$. The combination of Action Units (AU) most frequently engaged in expressing happy was AU 1 + 6 + 12 + 25 (9 times), followed by AU 1 + 12 + 25 (5 times). The other combinations contributed less to expressing happy in terms of frequency.

We also found evidence that the participants tended to share the same combination of Action Units when expressing different emotions. For example, three participants (P2, P6, and P14) used the combination of AU 6 + 12 + 25 when expressing *happy*, which was also used by another participant (P24) when expressing *confusion*. One participant (P2) used the combination of AU 1 + 5 when expressing *curious*, and the same combination was used by another participant (P28) when expressing *surprised*.

We observed that there was a difference in the combination of Action Units engaged in expressing happy by depending on participants' sociodemographic factors. Chi-square tests showed no significant difference among participants with regard to duration of visual impairment, onset of

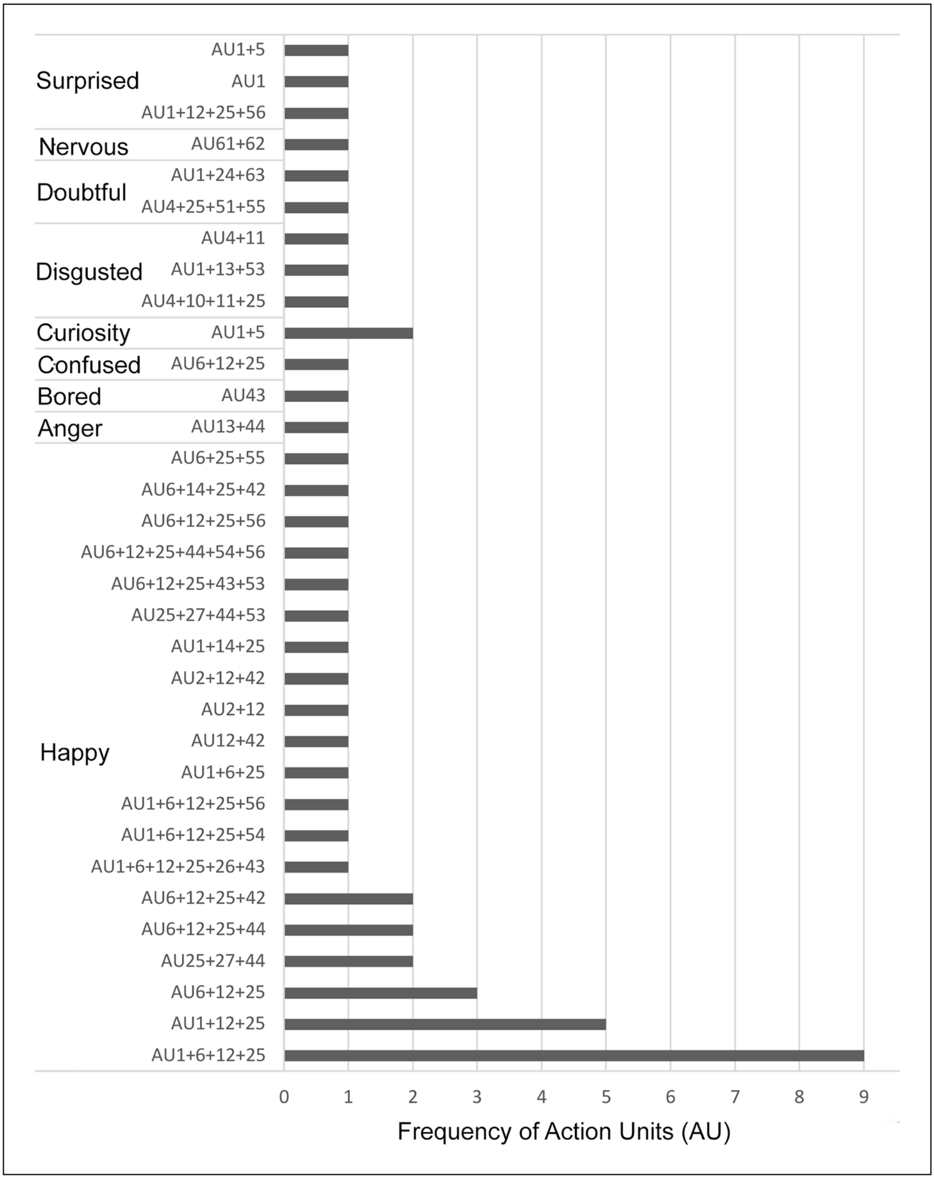

Figure 1. Frequency of Action Units (AU) engaged in expressing spontaneous emotions.
Note. AU1-Inner Brow Raiser, AU2-Outer Brow Raiser, AU4-Brow Lowerer, AU5-Upper Lid Raiser, AU6-Cheek Raiser, AU10-Upper Lip Raiser, AU11-Nasolabial Deepener, AU12-Lip Corner Puller, AU13-Cheek Puffer, AU14-Dimpler, AU24-Lip Pressor, AU25-Lips part, AU26-Jaw Drop, AU27-Mouth Stretch, AU42-Slit, AU43-Eyes Closed, AU44-Squint, AU51-Head Turn Left, AU52-Head Turn Right, AU53-Head Up, AU54-Head Down, AU55-Head Tilt Left, AU56-Head Tilt Right, AU61-Eyes Turn Left, AU62-Eyes Turn Right, AU63-Eyes Up.

visual impairment, age, gender, race/ethnicity, occupation, head of household, education, and marital status, but there was a significant difference between the participants with visual impairment and their peers with blindness, $\chi^2(18) = 30.00$, $p = .037$; between the participants who performed exercise regularly and their peers who did not so, $\chi^2(18) = 29.37$, $p = .044$; and between the

Table 2. Comparison of facial components in terms of the frequency of engagement in expressing happy.

	Lips	Eyebrows	Eyelids	Head
Cheeks	$\chi^2(1)=17.02$, $p<.001$	$\chi^2(1)=0.75$, $p=.39$	$\chi^2(1)=4.90$, $p=.027$	$\chi^2(1)=10.31$, $p=.001$
Lips	–	$\chi^2(1)=24.05$, $p<.001$	$\chi^2(1)=36.45$, $p<.001$	$\chi^2(1)=46.41$, $p<.001$
Eyebrows	–	–	$\chi^2(1)=1.88$, $p=.17$	$\chi^2(1)=5.83$, $p=.016$
Eyelids	–	–	–	$\chi^2(1)=1.19$, $p=.28$

participants with household income less than \$25,999 and their peers with household income between \$26,000 and \$51,999, $\chi^2(6)=12.80$, $p=.046$.

We also compared the combination of Action Units engaged in expressing emotions by different valence factors such as positive, negative, and neutral. For example, positive emotion included happy while negative emotion included anger, disgusted, confused, surprised, and nervous. Bored, curious, and doubtful were categorized in neutral emotion. A chi-square test showed that a significant difference was found in the combination of Action Units between positive emotion and neutral emotion, $\chi^2(24)=42.00$, $p=.013$ and between positive emotion and negative emotion, $\chi^2(28)=41.76$, $p=.046$.

Discussions

The data analysis resulted in a larger number of Action Units coded for happy as compared with other emotions. This study was originally not designed to intentionally induce negative emotions (e.g., depressed, guilt, and failure). Therefore, we ended up with the majority of the Action Units coded to explain positive facial expression (e.g., happy smile).

When each facial component (e.g., eyebrows, eyelids, lips, cheeks, and so on) was compared in terms of the frequency of engagement in expressing happy, lips contributed significantly to making facial expressions of happy. It suggests that although upper parts of facial components (e.g., eyelids and eyebrows) are somewhat engaged in expressing happy among people with visual impairment and blindness, they do not play a significant role compared with lower parts of facial components. If those with visual impairment and blindness wear a face mask, it would be challenging to recognize whether their emotion is positive, negative, or neutral, which will then negatively impact social interactions.

We also found that there were certain combinations of Action Units mostly engaged in expressing happy. For example, the combination of *eyebrows*, lips, and cheeks contributed mostly to the happy emotion expression. Similarly, it was observed that *eyelids* were also engaged along with lips and cheeks in expressing happy, the combination of which was, however, observed four times only. Both eyebrows and eyelids are considered as a facial component related to eyes; yet, as compared with eyebrows, eyelids typically show a smaller rage of movements such that the engagement of eyebrows would typically make the facial expression more distinctive. Therefore, the participants in this study might have used the eyebrows more frequently than the eyelids to clearly express their emotional states.

There were cases in which the same combination of Action Units was shared in expressing two different emotional expressions. For example, a participant showed a smiley facial expression for happy emotion but also made a smile for confusion emotion. The case was observed while the participant was confused about a certain social issue and simultaneously smiled. The participant explicitly stated that she felt confused. This result suggests that a simple facial expression of smile may not always refer to positive emotion. There is evidence in the literature that people tend to smile to express a wide range of different emotions, for example, people often "smile when lying (Ekman et al., 1988)," "smile when distressed (Ansfield, 2007)," and "smile when experiencing pain (Kunz et al., 2009)." Thus, we argue that human emotion processing, regardless of one's visual ability/disability, should be considered as a complex system that needs multidimensions to be adequately understood.

The combination of Action Units (AU) engaged in expressing happy was influenced by participants' sociodemographic factors. For example, the most frequently engaged combination was AU 1 + 12 + 25 among participants with visual impairment and AU 1 + 6 + 12 + 25 among those with blindness. AU 1, AU 12, and AU 25 refer to *inner brow raiser*, *lip corner puller*, and *lips*, respectively, all of which were found in those with visual impairment but also those with blindness. Yet, AU 6 (*cheek raiser*) was only found in those with blindness. It suggests that those with blindness make a bigger smile that would be caused by a greater engagement of lip corner puller and lips part, ultimately leading to significant engagement of cheek raiser. As this study did not focus on measuring the intensity of emotions and facial expressions, our future research will investigate the individual differences associated with the relationship between emotional intensity and spontaneous facial expressions among people with visual impairment and blindness. The effect of other sociodemographic factors on the engagement of Action Units (especially AU 6 in expressing happy, leading to a bigger smile) was also observed in those who participated in regular physical activities (versus those who did not so) and those who earned less household incomes (versus those who earned more). Our research findings are well aligned with prior research results. For example, Ekman et al. (1990) and Frank and Ekman (1996) argued that true enjoyment is expressed via certain sets of facial muscle movements, named *Duchenne smile* in which the "zygomaticus major muscle" would lift up the corner of the lips (e.g., AU 12 and AU 25) while the "orbicularis oculi muscles" lift the cheeks up (e.g., AU 6). The Duchenne smile is also involved with the movements of eyebrows (e.g., AU 1) (Ekman, 2021). All of the aforementioned Action Units would contribute to making a big smile. There is evidence that while non-Duchenne smiles tend to be expressed without AU 6, the Duchenne smile (induced by true enjoyment) is engaged with AU 6 (Frank et al., 1993). Smiles without AU 6 are less likely to be considered as genuine positive emotion, but they are likely referred to as false, miserable, or masking negative emotions (Ekman & Friesen, 1982). Given the literature, we could hypothetically argue that true enjoyment-based happy smiles are more likely to be observed in people with blindness than their peers with visual impairment; in those performing regular exercise than their peers with no regular exercise; and in those earning less household incomes. However, it should be noted that 14 other types of smiles exist (Ekman et al., 1990), such that our future research will further examine the relationships between Duchenne smiles and more various demographic factors of people with visual impairment and blindness.

We also sorted our emotion data by valence factors such as positive, negative, and neutral and compared the combination of Action Units engaged in expressing those emotions. The most frequently engaged combination of Action Units in expressing positive emotion was AU 1 + 6 + 12 + 25, followed by AU 1 + 12 + 25. However, none of those combinations were found in neutral and negative emotions. Neutral emotion is typically considered as one in which significant facial expression is less likely to be engaged; however, the participants in this study used various facial components (e.g., eyes, eyebrows, eyelids, and lips) in expressing neutral emotions. Neutral emotion does not always refer to one that expresses "nothing," but it can contain some meaning. Carrera-Levillain et al. (1994) empirically reported that neutral emotion often included strong messages and was, thus, found to be located in a region of the emotional dimension where low-arousal emotions and positive (or negative) emotions were typically observed (Russell, 1980). Said et al. (2009) also claimed that neutral faces can resemble "emotional" expressions, for example, neutral faces with positive valence often resemble happiness. Further research is needed to obtain a deeper understanding of the degree to which valence factors influence the spontaneous facial expressions in people with visual impairment and blindness.

Based on the literature review, we compared the engagement of facial muscle movements (i.e., AU codes) between sighted people and their peers with visual disabilities. For example, the participants in this study used AU 4 (brow lowerer) while expressing the emotion of disgusted. In the study by Galati et al. (1997), sighted people also used AU 4 in expressing *disgusted* but used more frequently than did people with blindness. This study found that AU 53 (head up) was engaged in expressing *disgusted* among the participants with visual disabilities. Galati et al. (2003) also observed that people with visual disabilities used AU 53 in expressing disgusted but used it more frequently than did sighted people. The study by Du et al. (2014) reported in more detail as to how a combination of multiple facial muscles were engaged in expression emotions although they did not include people with visual disabilities. They observed that sighted people used a combination of AU 12 (lip corner puller) and AU 25 (lips apart) in expressing *happiness*. The participants with visual disabilities in this study also used the same combination in expressing *happiness*. Du et al. (2014) found that a combination of AU 12 + AU 25 + AU 6 (cheek raiser) was often engaged in expressing *happiness*, while the same combination was also used by the participants in this study. Yet, we observed that those with visual disabilities also relied on other combinations in expressing *happiness* (e.g., AU 12 + AU 25 + AU 1 [inner brow raiser]; AU 12 + AU 25 + AU 1 + AU 6; and so on). It may be argued that people with visual disabilities use more various facial muscles in expressing *happiness* as compared with sighted people. Other previous studies (Chiesa et al., 2015; Cole et al., 1989; Kunz et al., 2012; Matsumoto & Willingham, 2009) also made effort to compare facial expressions between sighted people and their peers with visual disabilities; however, they merely focused on a particular emotion only (e.g., pain), did not use the FACS coding systems in analyzing facial expressions, did not identify different emotions in detail but simply categorized them into positive and negative emotions, focused on children with visual disabilities, and did not report combinations of FACS codes although they used the FACS codes in analyzing the facial expression data. This study contributed to advancing knowledge of how adults with visual disabilities use facial muscles in expressing various emotions in a natural setting, which was scientifically reported using the systematic coding system, FACS AU codes.

We also compared the facial expressions between the participants with visual disabilities in this study with their peers with visual disabilities in other studies. Galati et al. (1997) found similar results that AU 6 (cheek raiser) + AU 12 (lip corner puller) were primarily engaged in expressing joy among people with blindness. In addition to AU 6 and AU 12, the participants in this study often used AU 25 (lips part) in expressing happiness. It suggests that a smile presented by the participants in this study was larger enough to expose the teeth such that they looked happier. Yet, the participants in Galati's study were instructed to make effort to display facial expressions (i.e., a voluntary smile), while the participants in this study were not asked to do so but just being observed in a natural setting (i.e., a spontaneous smile). Thus, it can be argued that a spontaneous smile is likely to be associated with a higher intensity of happiness as compared with a voluntary smile among people with visual disabilities. AU 25 may be considered as an indicator to assess the intensity of happiness.

Galati's team repeatedly conducted similar studies afterward. For example, Galati et al. (2001) studied spontaneous facial expressions of congenitally blind children in Italy. They did not use the FACS coding system but used the Maximally Discriminative Facial Movement Coding System (MAX) instead. They found that for the emotion of joy, children with congenial blindness frequently showed "*mouth corners pulled back and slightly up*" and "*cheeks raised*" but none of them showed "*mouth opened wide*." It is consistent with their previous study (Galati et al., 1997). Another study by Galati et al. (2003) also confirmed that Italian children with congenital blindness primarily displayed AU 6 (cheek raiser) and AU 12 (lip corner puller) for joy.

However, it should be noted that Galati's study included participants with "congenital blindness" only, while this study included a combination of people with various vision loss status such as blindness, low vision (also known as visual impairment), early and late vision loss. Further research is needed to investigate the relationship between facial expressions and emotional intensity under the same condition (e.g., either voluntary or spontaneous emotional expression). In addition, Galati's participants were residents in Italy while participants in this study were residents in United Sates. Cultural differences in facial expression (Jack et al., 2012; Tsai & Chentsova-Dutton, 2003) may have led to the difference between the two studies. For example, American participants in the study by Scherer et al. (1988) showed significantly more facial expressions than did European participants for joy, sad, fear, and anger. Each group of Asian participants and American participants in the study by Dailey et al. (2010) were better at classifying facial expressions made by those with the same cultural background. There is a need to further examine the effect of cultural background on facial expressions made by people with visual disabilities.

Galati et al. (1997) also argued that AU codes for expressing disgusted were quite similar to those for joy in that AU 6 + AU 12 were primarily engaged in expressing both disgusted and joy. In this study, the participants also shared the combination of AU 6 + AU 12 + AU 25 for both disgusted and happy. It may be hypothetically argued that people with visual disabilities are likely to use similar or same facial expressions for different emotional states. Further research is needed to investigate the mechanism of sharing facial expressions for different emotions perceived by people with visual disabilities.

Limitations and future research

This study might have been affected by a few limitations. The study protocol was not designed to intentionally induce a particular emotion (e.g., negative emotions) of the participants, such that the majority of Action Units were coded for positive emotions such as happy. There were a group of participants who did not much make changes in facial expressions due to a personal health issue and who would not much rely on facial expressions while communicating with others in daily life. Thus, we excluded them from the data analysis. It implies that further research would be necessary to find an innovative way to read emotions perceived by those who are less likely to reveal their emotions via facial expressions.

We did not encounter the unmatched case where verbal responses are not aligned with facial expressions of emotions; for example, verbal responses indicated unhappiness while facial expressions indicated happiness. As this study was accomplished with a sample of 19 participants with visual disabilities, the research finding may not represent for the entire population with visual disabilities. In addition, we did not ask participants directly as to how they felt whenever they made facial expressions because we intended to focus on observing their facial expressions in natural settings (i.e., spontaneous expressions). If we kept interrupting and asking them why they made a certain facial expression, how they felt, and why they used certain emotional words, participants would probably be affected; thus, they would change the way they use facial expressions and even perceive different emotions during the interview, ultimately leading to research bias. Yet, future research will investigate as to how to identify such unmatched emotional expressions in a less invasive (or noninvasive) way.

Action units were coded manually. Yet, automated coding software cannot guarantee that accuracy (compared with human coding) is always superior. There is a report (Barrett et al., 2019) that accuracy decreases substantially when unconstrained conditions are taken (e.g., facial expressions observed in everyday life) as well as when facial configurations are not stereotypical. Participants in this study talked freely about their personal experiences (emotions and events) that they encountered in everyday life, and we just observed without interferences. There is lack of scientific evidence to show the validity of automated coding software when coding facial expressions of people with visual disabilities. Further research would be needed to evaluate the effectiveness of auto-coding versus human coding, especially for facial expressions made by people with visual disabilities.

This study was initially designed to conduct exploratory research instead of hypothesis-driven research. However, exploratory research is typically set to uncover possible relationships between variables, ending up with generating hypotheses for future research. The discussions aforementioned offered insights into hypotheses including "facial expressions for Duchenne smiles and non-Duchenne smiles are differently influenced by sociodemographic factors in people with visual disabilities," "people with visual disabilities use more various facial expressions in expressing happiness as compared with sighted people," "people with late onset vision loss show a larger smile than do their peers with early onset vision loss, especially when they feel happy spontaneously as compared with voluntarily," "American individuals use more facial muscles to express spontaneous emotions than do European individuals," "individuals with mild (or moderate) visual impairments are able to better understand facial expressions made by their peers from the same cultural background," and "individuals with severe visual impairments (or blindness) are able to better understand non-visual expressions (e.g., vocal) of emotions made by their peers with the same cultural background."

Conclusions

This study contributed to advancing knowledge of spontaneous facial expressions of emotions in adults with visual impairment and blindness. The research findings suggest that individual differences exist in the engagement of Action Units, which are likely to be influenced by individual characteristics associated with visual acuity, regular exercise, and annual household income. The research findings could be helpful for many other researchers and professionals in designing and developing emotion-aware technology (e.g., emotion recognition systems using Kinect sensors; Alabbasi et al., 2015) and societal interventions to facilitate interpersonal communication (e.g., teaching children with autism or Asperger syndrome to recognize emotions in others; Silver & Oakes, 2001). Future research should continue to investigate more various emotions that have a wide range of positive, negative, and neutral valence factors in people with visual impairment and blindness, including children and adolescents.

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