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自閉症類群障礙症兒童之臉部情緒辨識

Facial Emotion Recognition in Children with Autism Spectrum Disorders

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Facial Emotion Recognition in Children with Autism Spectrum Disorders

本論文係周承毅（R10429005）於國立臺灣大學職能治療學系所完成之碩士學位論文，於民國112年7月17日經下列考試委員審查通過及口試及格，特此證明。

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誌謝

入學前曾給碩班一些目標，第一是做好研究，第二是提升英文，第三是精進口語表達。時隔兩年，回頭檢視下才驚覺每天不起眼的日常都在默默累積養分，原來自己能成為當初幻想的樣貌、原來自己是堅韌的，原來自己是能被期待的。

職能治療時刻提醒我，能有這些體悟是環境、任務還有自己互動下的結果，都要由衷感謝。我的指導教授湉妮老師就佔了其中兩部分，從我踏入公衛大樓七年以來，老師都一直支撐著我，不評價地讓我做著一切想做的事，同時又會指派一些具挑戰的事，使我能在很安心的環境下持續成長，從沒停下。短短幾句話輕描淡寫，卻是我很珍惜的師生關係。第二個要感謝顥齡老師，總是給予我很多研究上的建議，偶爾也會經過辦公室關心我們中午要吃什麼，能受到老師共同的指導真的很幸福。再來是我的同學家樂，剛認識時你的無禮就惹毛了我，直到後來才發現直白是你的特色；雖然不太願意承認，但你讓我的碩班生活值得懷念。另外也是我的同學品蓁，我們默默走遍了好多的地方，上山又下海，未來仍由妳持續關照，願我們出社會後能如現在一樣。再來還有好多想感謝的夥伴，感謝凱傑一路以來的提攜，作為我在研究上的榜樣，希望能早日吃到喜酒；感謝芷琦總是接納兩個學長沒水準的玩笑，溫柔以待，受過訓練的妳一定能勇敢為自己發聲；感謝不知道該說是學妹還是學姊還是同學的映璇、蕎羽、雍蓉、博雅、人瑜以及喻安，共事的時光令人懷念；感謝文豐、采瑜以及淨維，你們不求回報的協助我都牢記在心。還有其他好多的朋友們，即便我常常懶得回訊息，你們仍把我放在心上，謝謝你們把關著我的身心健康，我也會努力緊抓著與你們的情誼不放。

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中文摘要

臉部情緒辨識為孩童發展社交互動的一項重要先備技巧。根據文獻回顧，自閉症孩童在臉部情緒辨識上易出現困難，此缺陷可能受到他們非典型的視覺處理模式影響。目前已有實證支持臉部情緒辨識以及自閉症視覺處理的關聯，但過往研究中所選用之視覺處理操作型定義尚不完善，研究結果解釋可能有偏差。有鑑於此，本研究完整回顧過往自閉症視覺處理相關理論——弱中心聚合、增強知覺功能、局部優先，用以探討其對自閉症孩童臉部情緒辨識的影響。此外，為了解自閉症孩童臉部情緒辨識困難是否體現於日常社交表現，本研究亦嘗試建立臉部情緒辨識與社會適應功能之間的關聯。

本研究預計招收 7 至 12 歲之自閉症及典型發展孩童。孩童將優先接受臺灣版自閉症行為檢核表以區辨有無自閉特質，並以瑞文氏推理測驗排除認知障礙者。納入之受試者將接著進行臉部情緒辨識測驗及文蘭適應行為量表。在臉部情緒辨識測驗中，孩童將接受四種測驗情境（無策略引導之無遮罩、有策略引導之無遮罩、口罩遮罩、墨鏡遮罩）以建立不同情境下之臉部情緒辨識表現。該結果將用來釐清自閉症與典型發展孩童在臉部情緒辨識上的差異，以及自閉症視覺處理型態對臉部情緒辨識的影響。文蘭適應行為量表將用以檢驗臉部情緒辨識以及社會適應功能間的關聯。整個實驗流程約 1.5 小時完成。

共有 25 位自閉症孩童及 24 位正常發展孩童參與本研究。臉部情緒辨識測驗結果顯示，自閉症組相較典型發展組在無遮罩的情境下有較低的正確率；自閉症組本身在無遮罩相較遮罩情境有較高的正確率；自閉症組本身在無遮罩情境中的兩個情境以及有遮罩情境中的兩個情境都沒有表現上的差異。本研究並未發現任何臉部情緒辨識測驗結果以及文蘭適應行為量表分數間的關聯。

本研究結果證實視覺處理型態會影響自閉症孩童之臉部情緒辨識表現。與自閉症之弱中心聚合知覺特徵吻合，自閉症孩童能夠留意多方臉部五官特徵，但較難以將資訊有效整合以推論他人情緒。增強知覺功能以及局部優先之視覺特徵似

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乎無法用來解釋自閉症在辨識臉部情緒的困難。本研究量測之臉部情緒辨識表現似乎無法類推至孩童社交適應功能，顯示社交適應功能可能無法從此類認知需求較少的能力所反映。關於未來研究方向，建議能以眼動追蹤技術來更加釐清自閉症孩童之視覺處理特徵對臉部情緒辨識的影響，亦建議多探討臉部情緒辨識以及社交表現之間的中介變項。

關鍵字：臉部情緒辨識、視覺處理模式、弱中心聚合、學齡孩童、社會適應功能

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Abstract

Emotion recognition is a fundamental skill for successful social interaction. Based on the literature review, children with autism spectrum disorders (ASD) have difficulty in recognizing others' facial expressions, which may be explained by their atypical visual processing styles. Few studies have examined the relationships between facial emotion recognition (FER) with visual processing, yet visual processing has not been comprehensively conceptualized. Given the knowledge gap, the present study aims to investigate the influence of visual processing in terms of weak central coherence (WCC), enhanced perceptual functioning (EPF), and local precedence on FER in children with ASD. Moreover, the relationships between FER with social adaptive functions were established to generalize the FER to daily social performance.

ASD and typically developmental (TD) children aged 7 to 12 years old were recruited. Participants were screened for ASD traits using the Autism Behavioral Checklist - Taiwan Version (ABCT), and for intellectual disabilities using Raven's Progressive Matrices (RPM). The included participants continuously performed the Facial Emotion Recognition Task (FER Task) and the Vineland Adaptive Behavior Scale 3 (VABS). In the FER Task, three conditions (uncovered without guide, uncovered with guide, covered-mask, and covered-colored-glasses) are designed to capture the FER performance. The results could explain the group difference in FER and the effect of visual processing on FER in children with ASD. The VABS was used for investigating the relationships between FER with social adaptive functions. The whole experimental session took 1.5 hours approximately.

A total of 25 children with ASD and 24 children with TD participated in this study. The results of the FER task revealed that the ASD group had lower accuracies in the uncovered conditions compared to the TD group. However, within the ASD group, the

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accuracies in the uncovered conditions were higher than those in the covered conditions, and no differences in accuracies were found within the uncovered and covered conditions. No significant relationships between the FER task and the VABS scores were observed in this study.

This study suggests that visual processing has an impact on FER performance in children with ASD. These children have difficulties integrating information from facial properties as efficiently as age-matched TD individuals, which is consistent with the perceptual dysfunction in ASD according to the WCC theory. The EPF and local precedence theories do not appear to explain the FER difficulties in children with ASD. No significant relationships were found between the FER and the VABS scores, indicating that social performance may not be influenced by these abilities without high cognitive demands. The issue of FER in children with ASD could be better understood by employing eye-tracking techniques and exploring potential mediators between FER and social performance in future research.

Keywords: Facial emotion recognition, visual processing, weak central coherence, school-aged children, social adaptive functions

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Chapter 1 Introduction

1.1. Autism Spectrum Disorders

Autism, introduced by Leo Kanner in "*Autistic Disturbances of Affective Contact,*" describes the inability to relate oneself with others, and the obsessive insistence on sameness (Kanner, 1968). In recent years, for awareness of high heterogeneity in autistic symptoms, autism was suggested to be considered as a spectrum, rather than a classification. Therefore, in DSM-5, autism was renamed as autism spectrum disorder (ASD). Previous diagnoses such as Rett's disorders, Asperger syndrome, and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) no longer existed; instead, they were all suggested to be parts of ranges in the autism spectrum. Based on a common definition, ASD is a neurodevelopmental disorder characterized by deficits in social communication and interaction, and the presence of repetitive, restricted, and inflexible behavior patterns or interests (American Psychiatric Association, 2013). In Taiwan, it was reported that prevalence ranges from 1 to 1.79 per 100 people, with rising incidence in these years (Chen et al., 2019; Chien et al., 2011). These increasing numbers demonstrate the large population and thus have shed light on the importance of studying children with ASD.

Within social domains, children with ASD manifest difficulties in pragmatic use, poorer joint attention, lack of mutual and meaningful conversations, and a lower level of theory of mind, which may pose a negative effect on the quality of interactions with others (Bottema-Beutel, 2017; Bruinsma et al., 2004; Chiang et al., 2008; Friedman & Sterling, 2019; Nejati et al., 2021). One of the fundamental skills contributing to successful social interaction is the emotion recognition. By definition, facial emotion recognition (FER) is the process of implicitly perceiving others' facial properties, linking the information to the knowledge of emotions, and inferring others' emotional states (Adolphs, 2002).

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Previous studies indicated that children who cannot explain others' facial expressions are less likely to behave altruistically, and they could develop negative attitudes toward themselves and continuous feelings of loneliness (Castro et al., 2018; Izard et al., 2001). Since FER skill is the basis of interpersonal relationships which are the main problems in ASD, FER may also be one of the critical factors of social impairments in ASD children. In the following sections, the nature of emotion, the FER performance, and its possible mechanism specialized in ASD were reviewed.

1.2. Emotion Recognition in Children with ASD

1.2.1. Introduction of Emotion

Emotion, a dynamic psychological structure, can be portrayed as a change in physiological pattern, appraisal mechanism, and behavior in response to antecedent events or internal thoughts (Ekman, 1992; Fridlund et al., 1987; Gazzaniga et al., 2010). Take sadness for instance, it is considered the product of facing loss. Sad people may frown, shed tears, and move down corners of the mouth, with activated insula and anterior pole (Eugène et al., 2003; Harmon-Jones et al., 2016). They may reject the fact of loss, hampering motivation to solve the problem, and eventually develop a sense of hopelessness (Lazarus, 1991).

A noteworthy approach to emotions is Ekman's basic emotion model. Once, he and his colleagues required subjects from different regions to link emotional terms to photographs with facial expressions. They found that people can label happiness, anger, fear, sadness, disgust, and surprise with high agreement regardless the cultural differences (Ekman et al., 1969). These emotions were then identified as the basic emotions. Since this classification is easily applied, and the six emotions are deemed representative of the emotions that most humans have experienced, the basic emotions remain the dominant

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categorization across studies of FER (Landowska et al., 2022).

1.2.2. Overviews of Emotion Recognition in Children with ASD

FER is a skill underlying social performance in ASD, which has been well discussed in recent decades. Results with strong evidence pointed out that ASD performed significantly worse than typically developmental (TD) individuals on FER tasks, especially reflected through abnormal eye gaze and brain waves (Chung et al., 2014; Harms et al., 2010; Lozier et al., 2014; Uljarevic & Hamilton, 2013). The results seem not affected by the ASD's intellectual abilities and task type, implying that the difficulties of FER, exist prevalently in the ASD population, regardless of matching or labeling emotional terms to others' facial expressions. The effect of age is quite controversial. In TD children, convergent results pointed out that FER skills will become elaborate by age, and children are likely to reach adult-like performance at around 10 years old (Chronaki et al., 2015; Lawrence et al., 2015; Vicari et al., 2000). In ASD, conversely, one argued that the impairments of FER will be magnified by age (Lozier et al., 2014), whereas others claimed that age does not moderate FER (Chung et al., 2014; Uljarevic & Hamilton, 2013). From the above findings, it could be inferred that ASD may have little or even negative progress on FER as they grow up, yielding a distinct developmental trajectory.

Two probable mechanisms explaining the FER in ASD were highlighted in the meta-analysis of Lozier et al (2014). The first is the social reciprocal hypothesis. It pointed out that FER-related neural systems such as amygdala and fusiform gyrus will activate properly in support of reacting in a social interaction (Kliemann et al., 2012; Leppänen & Nelson, 2009); and also, these neural structures would be shaped by experiences. The reciprocal relationship between neural maturation and social experiences then scaffolds individuals to develop more specialized behaviors in the face of different social contexts.

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But, in ASD, deficits in social interaction such as decreased eye gaze to human faces appearing at a young age may restrict the development of neural organization. The immaturity of these structures may in turn hinder them from participating in more complex social environments, leading to unprogressive social skills, for instance, the inability to mentalize others.

The other explanation is the atypical visual processing. A previous study indicated that ASD perceived human faces with inactivation of the fusiform gyrus which is an indicator of the social brain and the visual expertise (Schultz et al., 2000). Similarly, another study pointed out that ASD showed delayed latencies and smaller amplitude of N170 which is related to holistic processing when looking at human faces (Black et al., 2017). In general, the face is considered a holistic configuration comprised of local facial features, and individuals with mature visual processing are likely to perceive faces as a whole to immediately extract social information (Gauthier et al., 2009; Teunisse & de Gelder, 2003). However, ASD is extensively observed attending to a single object rather than considering the full situation. They may focus on specific facial properties or even unrelated body parts, missing the integrated information conveyed through the entire affective expressions. This may pose different interpretations from ASD with TD when looking at the same face.

To summarize, it is suggested that FER is a prevailing and persistent issue in ASD, which is related to insufficient social experiences and local-oriented visual processing. To clarify the mechanisms of FER in ASD, the relationships between FER with social performance, and with visual processing were addressed in the following sections.

1.2.2.1. Social Performance and Emotion Recognition

FER is a fundamental skill contributing to interpersonal relationships. It is reported

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that ASD individuals who have difficulties in recognizing others' facial emotions could also have problems in inferring others' mental states (Trevisan & Birmingham, 2016). It may be challenging for them to respond to others appropriately in the social context, and over time, they may lose the motivation to build connections with others, which in turn restrict the opportunities to practice reading others' expressions (Harms et al., 2010; Høyland et al., 2017; Williams & Gray, 2013a).

To more generalize this relationship to daily living performance, the relationships between FER with social adaptive functions (the fulfillment of life social tasks following individuals' ages) were reviewed. In a meta-analysis, with five studies included, a low to moderate relationship ($r = 0.39$) between FER with social adaptive functions was established for the ASD populations (Trevisan & Birmingham, 2016). This result partially goes along with the social reciprocal hypothesis, supporting that impairments in FER may influence social interaction or insufficient social experience may restrict the development of FER. Despite making sense, this result should be viewed cautiously since the participants' ages and diagnoses in these studies were varied (15 PDD children aged from 7 to 15 years old in Braverman et al., 1989; ASD preschool children in Williams & Gray, 2013a; Williams & Gray, 2013b; and ASD adolescents and adults in García-Villamisar et al., 2010; Wallace et al., 2011). For the school-aged children, the critical period of developing FER, the empirical evidence is relatively insufficient. The validation of the relationship between FER with social adaptive functions in children with ASD is still needed.

1.2.2.2. Visual Processing and Emotion Recognition

The imbalance between global processing with local processing is the main issue regarding visual processing in ASD. One perspective referring to weak central coherence

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(WCC) is that ASD individuals have the attenuated ability to gather global information and then draw out meaning in context (Frith & Happé, 1994). The well-known evidence is the Embedded Figures Test (Shah & Frith, 1983). Children with ASD and clinical control were required to figure out a simple figure hidden in a complex drawing. The results suggested that, compared to the control group, ASD children had difficulty in forming a gestalt in their mind, making them find the local figure more easily. Another perspective, enhanced perceptual functioning (EPF) proposed that ASD has superior low-level perceptual abilities such as visual discrimination, directing them to fix on surface properties rather than perceiving the hierarchical structure of stimuli. (Mottron & Belleville, 1993; Mottron & Burack, 2001). In one study, individuals with ASD and TD were given configural grouping tasks (combine components into configuration) and a disembedding task (identify an isolated letter and a letter hidden in a figure) (Mottron et al., 2003). The results showed that, in the disembedding task, ASD demonstrated comparable reaction time (RT) in identifying the isolated letter and the embedded letter, whereas TD reacted much slower to the embedded letter compared to the isolated letter. Since there were no group differences in configural grouping tasks, the authors did not consider the insusceptibility to the global-to-local interference as the consequence of impaired global processing. Instead, it was the product of enhanced local processing inhered in ASD. To sum up, both WCC and EPF assumed that the visual processing in ASD is somewhat abnormal, with one proposing worse global processing compared to TD, and the other suggesting better local processing compared to global processing within ASD.

In recent versions of WCC and EPF, the task context was highlighted as an important factor for visual processing in ASD, implying that they may display different processing styles by conditions. Task instruction is an influential experimental manipulation to

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compare performance under different contexts. Two noteworthy studies have examined the effect of task instruction on ASD's visual processing. The first one is the study of Plaisted et al (1999). Children with ASD were given two modified Navon's attentional tasks in which the stimulus is characterized as a big letter comprised of small letters. In the divided attention task, participants were required to monitor global and local levels of stimuli to figure out the target letter. In the selective attention task, participants were cued to attend to either the global or local level and then reported what they had seen. The results revealed that ASD children, alike TD individuals, performed better and faster in global trials compared to local trials in the selective attention task. This finding supported the influence of task instruction. Children with ASD could demonstrate similar performance with TD children under the cuing condition. However, in the divided attentional task (without cuing), they performed better in local trials (fewer errors and shorter RT) than those in the global trials. From these findings, it could be inferred that the global processing in ASD is unaffected. They may perform well once the instructions or cues are given.

Similarly, another study also tested visual processing in ASD children with Navon's tasks (Koldewyn et al., 2013). Participants were shown two conditions, one of which demands the children attend either global or local level, and without any instructions for the other one. The results showed that, in the condition without instructions, the percentage of seeing global level was significantly lower in ASD children compared to TD children. However, in the condition with instructions, ASD did not display deficits in global versus local trials.

Combining the findings from these two studies, ASD may not be deficient in global processing since the global processing was comparable to local processing under instructions. However, in spontaneous settings, ASD looks at the local level prior to the

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global level of stimuli, which may lead to inadequate performance in attending to the global level compared to TD individuals. This trait, using local processing naturally, was then defined as the local precedence effect. Since ASD seems to retain global and local processing abilities, visual processing in ASD is no longer considered abnormal, instead, it should be atypical. In summary of the visual processing in ASD, the WCC emphasized that ASD has worse global processing than TD, and the EPF pointed out that local processing prevails over global processing in ASD. The local precedence hypothesis supplemented the influence of task instruction, proposing that ASD has the potential to attend to the global level after they are given instructions or cues.

Although studies have explained the impairments of FER in ASD might be due to atypical performance of visual processing, few studies have designed experiments to understand this connection. Two articles have been found. For example, children with ASD and clinical control were given two types of stimuli which are Navon's stimulus (global-local processing) and photographs with emotional faces (Gross, 2005). The results pointed out that, compared with the control group, ASD made fewer global responses in Navon's task and more errors in matching emotional faces. Besides, there was a significant relationship between visual processing and FER ($r = .58$). For another example, Asperger (AS) and TD adults were shown emotional photographs with different degrees of spatial frequency (clear, slightly blurred, strongly blurred). The results pointed out that AS demonstrated difficulties in FER with significant group differences when viewing strongly blurred photographs, implying that AS was not skilled at recognizing emotions from the global facial configuration. Rather, they may depend on local facial properties with clear boundaries to extract emotional information (Kätsyri et al., 2008). These two studies provided evidence that impairment of FER may result from the attenuated global processing in ASD, supporting the WCC. However, this explanation

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might be incomprehensive since the task context or instruction was not taken into consideration. If the successful FER could be predicted by attending to facial configuration rather than discrete properties, the ASD might demonstrate improvement in FER when they were prompted to use global processing.

To summarize, the impaired FER was explained by the attenuated global processing in ASD. This conclusion should be taken cautiously since the global processing was not comprehensively evaluated in the previous studies. The task instruction should be included to profile the nature of visual processing in ASD beforehand.

1.3. Purposes of the Present Study

In summary of the previous studies, the mechanism of FER in children with ASD and the relationships between FER with daily performance remains uncertain. Hence, this study aims to investigate the influence of visual processing on FER in children with ASD. Three specific purposes are as follows:

(a) Profile the FER performance in ASD children with TD children.

(b) Examine the role of visual processing on FER in children with ASD.

(c) Establish the relationships between FER with social adaptive functions in children with ASD.

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Chapter 2 Methods

2.1. Participants

Children with ASD and TD were recruited from hospitals, clinics, schools, or associations. For the ASD group, the inclusion criteria are as follows: (1) aged between 7 to 12 years old, (2) diagnosed with ASD, (3) scored higher than the cut-off point of Autism Behavior Checklist-Taiwan Version (ABCT). Children were excluded if (1) their intellectual ability was below the 5^{th} percentile rank screened by Raven's Progressive Matrices (RPM), (2) severely impaired in visual acuity (cannot see the screen after visual correction). For the TD group, the inclusion criterion is aged between 7 to 12 years old. Children were excluded if (1) they scored higher than the cut-off point of ABCT, (2) their intellectual ability was below the 5^{th} percentile rank screened by RPM, (3) diagnosed with other mental disorders or developmental delays, or (4) severely impaired in visual acuity (cannot see the screen after visual correction).

For the power analysis, a previous study indicated that individuals with ASD perceived global-level stimulus slower than the TD (Van der Hallen et al., 2015). The effect size (hedge's g = .43), combined with $\alpha = 0.5$ and power = 0.80, reveals that 44 participants calculated by G*Power 3.1 in total is sufficient. Given the potential exclusive participants due to failure in screening tests, 50 participants in total (25 participants in each group) should be recruited.

2.2. Measurements

2.2.1. Screening Tools

2.2.1.1. Autism Behavioral Checklist- Taiwan Version (ABCT)

ABCT is a screening test for uncovering the potential ASD in individuals aged 3 to 15 years old. 47 items are included in this checklist, with the sensory, relating, body and

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object use, language, social and self-help subtests (Krug et al., 1980). Possible ASD is suggested if the child scored more than or equal to 7 points rated by the caregivers or teachers. For the psychometric properties, ABCT is demonstrated with acceptable to excellent internal consistency reliabilities (Cronbach's alphas = 0.95 and 0.75-0.87 for subscales), good test-retest reliability (r = 0.89), and criterion validity（黃君瑜、吳佑佑，2013）. It takes about 10 minutes to complete this test.

2.2.1.2. Raven's Progressive Matrices (RPM)

RPM is used for screening out the participants with potential intellectual disabilities (who rank less than or equal to 5^{th} PR) in the present study. The eductive ability is the process of identifying problems and then resolving them with corresponding evidence (Raven & Court, 1938). In this task, participants were asked to choose a puzzle that was most likely to fit the missing one among several puzzles. The version of Coloured Progressive Matrices (CPM) and Standard Progressive Matrices – Parallel (SPM-P), which contain 36 and 60 items, were implemented in this study. Good to excellent internal consistency reliabilities (Cronbach's alphas = 0.90), acceptable test-retest reliability (rs ranging from 0.73 to 0.87), and criterion validity (correlated with intelligence tests and academic performance) were examined for Taiwanese populations （陳榮華、陳心怡，2006）. This test is required to be completed within 30 minutes.

2.2.2. Facial Emotion Recognition Task (FER Task)

FER Task is developed to investigate the performance of recognizing others' emotional states. Stimuli were presented as photographs selected from the Database of Facial Expressions of Professional Performer （陳建中等，2013）, and the selection criteria are shown in Appendix A. All the photographs were corrected into the same size

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with a length of 384 pixels (10.16 cm) and a height of 480 pixels (12.7 cm). Two of the photographs, composing a photograph dyad, were placed with a horizontal distance of 600 pixels (15.88 cm) onto a white background, shown on a 13-inch MacBook Pro laptop monitor. These two photographs, with different emotions but matched on the performer's gender and emotional intensity, were randomly selected and displayed using Psychopy in Python programming.

Thirty practice trials and 360 formal trials in total were constructed in this task (Appendix B). The practice trials were the Red Dot Task and Geometric Recognition Task, designed for normalizing reaction time (RT) and familiarizing participants with task requirements. The formal trials were the FER Task, which can be divided into the uncovered-without-guide condition (5 trials x 6 emotions x 3 intensities, 90 trials), the uncovered-with-guide condition (5 trials x 6 emotions x 3 intensities, 90 trials), and the covered conditions (5 trials x 6 emotions x 3 intensities x 2 occlusions, 180 trials). The uncovered-without-guide condition was designed to establish the spontaneous performance in FER. No instruction regarding eye gaze positions should be given to the participants. In the uncovered-with-guide condition, to force the participants to use global processing, participants were asked to read the emotion from the whole face before recognizing it. In the covered conditions, photographs were edited into wearing masks or colored glasses. Since partial facial properties were occluded, participants could only attend to the remained properties, employing their local processing.

For the procedure, in the practice trials, participants were asked "Where is the red dot? If it appears on the left of the monitor, please press the left key; if it appears on the right, please press the right key." and "Which is circle (or triangle)? If the answer is the left one, please press the left key; if the answer is the right one, please press the right key." before each block to make sure the participants understand the task requirement. In each

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trial, a sized 2 x 2 cm fixation appeared on the center of the monitor for one second, and then the two figures (one target figure and one confounding figure) appeared and stayed on the monitor. The participants were encouraged to report as fast as they can. The inter-trial interval (ITI) was one second.

After practice trials, words of six basic emotions were shown on the monitor, and the experimenter asked "What does it (happy, sad, angry, disgusted, fearful, or surprised) mean to you?" to ensure participants knew of each emotion. Then the experimental trials started. Participants were first presented with the uncovered-without-guide condition, followed by the uncovered-with-guide condition or the covered conditions randomly. The procedures were the same as the design of the practice trials. In the uncovered-without-guide condition, participants were shown uncovered photographs. No more instructions than "Which person looks happy (or sad, angry, disgusted, fearful, surprised)? If the answer is the left one, please press the left key; if the answer is the right one, please press the right key." were given. In the uncovered-with-guide condition, participants were shown uncovered photographs. They were guided "Please look at the whole face. The whole face comprises eyebrows, eyes, nose and mouth. Which person looks happy (or sad, angry, disgusted, fearful, surprised)? If the answer is the left one, please press the left key; if the answer is the right one, please press the right key." Last, in the covered conditions, participants were shown covered (wearing masks or wearing glasses) photographs. The instructions were "Please look at the eyes (mouth). Which person looks happy (or sad, angry, disgusted, fearful, surprised) to you? If the answer is the left one, please press the left key; if the answer is the right one, please press the right key." The accuracies and the RTs of these conditions were collected for further analysis. After a complement of experimental trials, the experimenter asked "How do you recognize happy (or sad, angry, disgusted, fearful, surprised) from a face?" to understand participants' eye

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gaze positions. The duration of this task was approximately 40 to 50 minutes.

2.2.3. Vineland Adaptive Behavior Scale 3 (VABS)

VABS is a tool used for assessing adaptive behaviors which is the performance corresponding to the individuals' age and cultural expectancy (Sparrow & Cicchetti, 1985). The children form (for children aged 6 to 12 years old) was used in this study. The scale comprises communication, daily living skills, socialization, and motor skills domains. The socialization domain, assessed in this study, can be then separated into interpersonal relationships (33 items), play and leisure (31 items), and coping skills (32 items) subdomains. Parents or caregivers were required to rate the frequency of stated performance to never (0 points), sometimes (1 point), and usually (2 points). VABS has been validated with acceptable internal consistency reliabilities (r = 0.73 – 0.96), good test-retest reliabilities (r = 0.86), and criterion validity（張正芬等，2020）. The test could be completed within 30 minutes.

2.3. Procedure

Three stages were included in the present study. First, informed consent from participants was received. Second, children were led to a bright room to perform RPM, and the caregivers were invited to another place to fill in demographic information and ABCT. Potential ASD participants who scored below 7 points in ABCT or scored less than the 5th percentile rank in RPM were excluded. Potential TD participants who scored over 6 points in ABCT, or scored less than 5th percentile rank in RPM were also excluded. Last, the included children were tested with the FER Task, and their caregivers were asked to complete the socialization subtests in VABS. The whole experimental procedure is no longer than 1.5 hours.

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2.4. Hypotheses

(a) Profile the FER performance in ASD children with TD children.

Several reviews and meta-analyses indicated that FER is impaired in ASD. Predictably, the ASD may display lower accuracies and increased RTs across all conditions in the FER Task compared to the TD.

(b) Examine the role of visual processing on FER in children with ASD

Based on the WCC, ASD may display poorer global processing which is uncovered-with-guide condition compared to TD. The local precedence proposed that ASD can shift their default visual processing style to global processing under instruction. Hence this study predicts that children with ASD may perform better FER in uncovered-with-guide condition than in uncovered-without-guide condition. Based on EPF, ASD may display the advantages of local processing. Thus, unlike children with TD, they might demonstrate similar performance in covered conditions with the uncovered-without-guide condition.

(c) Establish the relationships between FER with social adaptive functions in children with ASD

A previous review indicated that FER has low-to-moderate relationships with social adaptive functions in ASD populations (Trevisan & Birmingham, 2016). It included five studies, with one for PDD children ($r = 0.69$ in Braverman et al., 1989), two for ASD adolescents and adults (rs range from 0.37 to 0.42 in García-Villamisar et al., 2010; Wallace et al., 2011), and two for ASD preschool children (rs range from 0.21 to 0.36 in Williams & Gray, 2013a; Williams & Gray, 2013b). Since evidence for school-aged ASD children remains insufficient, we preliminary predicted a low-to-moderate correlation coefficient in this population.

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2.5. Statistical Analysis

Accuracies and RTs in the FER Task were analyzed. The averaged accuracies were calculated by the percentage of correct items to the total items in each condition. The averaged RTs were presented as the trimmed means of normalized RTs in each condition. First, the RTs were normalized by subtracting the RTs in experimental trials from the averaged RT in red dot trials to assess the processing duration of FER. Then, the RTs of incorrect trials were removed. Last, ten percent of each of the highest and lowest RTs were trimmed, and the remained RTs were averaged.

For profiling the FER performance in children with ASD and TD, the descriptive statistics were presented, and the possible covariates were investigated using the Pearson correlation analysis or the Mann-Whitney U test. For investigating the role of visual processing on FER in ASD, two-way analyses of variance (Two-Way ANOVA) were performed to examine the interaction between groups and conditions, and differences between groups (TD versus ASD) and the conditions (uncovered-without-guide, uncovered-with-guide, covered-mask and covered-colored-glasses). Last, Pearson's correlation analysis was used again to establish the relationships between FER with social adaptive functions in ASD.

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Chapter 3 Results

In this chapter, the (1) descriptive data of the FER task, (2) results of the FER task including between-group and within-ASD-group differences, and (3) the relationships between the FER task and the VABS were presented respectively in the following sections.

A total of 29 ASD children and 24 TD children were recruited. Four participants with ASD were excluded from this study due to suspected intellectual disabilities indicated by the RPM. Among the ASD group, nineteen participants were also diagnosed with attention deficit hyperactivity disorder (ADHD) or attention deficit disorder (ADD). Twelve of them were under the influence of Ritalin, Ritalin LA, Concentra, or Atomoxetine while participating in this study. One participant had comorbid panic disorder, one had Tourette's syndrome, two had learning disabilities, and one had a history of preterm and cerebral palsy. All participants in the TD group did not receive any diagnoses of mental disorders or developmental delays. A final sample consisting of 25 ASD children and 24 TD children was included in this study.

The demographic information and scores of the ABCT, RPM, and VABS for the included participants are presented in Table 1. A comparison between the TD and the ASD groups revealed significant differences in scores of the RPM ($t = 2.653$, $p = 0.011$), the ABCT ($t = -11.111$, $p < 0.001$), and the VABS ($t = 10.272$, $p < 0.001$). These indicate that the ASD group has lower nonverbal intellectual abilities, more autistic traits, and a lower level of social adaptive functions compared to the TD group. The two groups also demonstrated a difference in proportion in gender ($X^2 = 7.579$, $p = 0.006$), with more females in the TD group. No difference in age was found between the two groups ($t = -0.403$, $p = 0.689$).

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3.1. FER Performance of ASD and TD Children

The accuracies were compared between 25 ASD and 24 TD children, while RTs were analyzed based on 21 ASD and 22 TD children. The RTs from two TD children were excluded due to missing values, and from four ASD children were excluded as they exceeded two standard deviations above the average of the ASD group. The accuracies and RT in the FER task are respectively presented in Table 2 and Table 3. Relationships between the accuracy of the uncovered-without-guide condition and the participants' characteristics were analyzed to understand the possible confounding effects. Neither significant relationships between the FER and the RPM ($r = 0.257$, $p = 0.216$ for the ASD group; $r = -0.107$, $p = 0.618$ for the TD group), nor the gender differences in the FER were observed ($U = 32.000$, $p = 0.243$ for the ASD group; $U = 42.000$, $p = 0.108$ for the TD group). Significant relationships between the FER and age were found in both the ASD group ($r = 0.520$, $p = 0.008$) and the TD group ($r = 0.405$, $p = 0.050$).

3.2. Effects of Visual Processing on the FER

The accuracies of FER are shown in Table 2, Figure 1 and Table 4. No significant interaction effect between groups and conditions ($F_{3,47} = 0.823$, $p = 0.483$, $\eta^2_p = 0.017$) but a small effect size was found. Results revealed a marginal main effect of groups with higher accuracies in the TD group ($F_{1,47} = 4.019$, $p = 0.051$, $\eta^2_p = 0.079$), and a significant main effect of conditions which indicates better performance in the uncovered conditions compared to the covered conditions ($F_{3,47} = 31.845$, $p < 0.001$, $\eta^2_p = 0.404$). Simple main effects were then examined based on the Bonferroni t-test. Results showed that the ASD group had lower accuracies compared to the TD group in the uncovered-without-guide ($p = 0.018$) and the uncovered-with-guide ($p = 0.020$) conditions. No group differences were found in the covered-mask ($p = 0.267$) and the

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covered-colored-glasses ($p = 0.221$) conditions. The within-ASD-group results indicated higher accuracies in the uncovered conditions compared to the covered conditions ($ps < 0.05$). No differences were observed within the uncovered conditions ($p = 1.000$) and the covered conditions ($p = 1.000$). For the RTs, results were shown in Table 3, Figure 2, and Table 5. Results neither showed an interaction effect of groups and conditions ($F_{3,41} = 0.346$, $p = 0.756$, $\eta^2_p = 0.008$), nor main effects of groups ($F_{1,41} = 2.638$, $p = 0.112$, $\eta^2_p = 0.060$) and conditions ($F_{3,41} = 2.328$, $p = 0.090$, $\eta^2_p = 0.054$).

Table 6 and Table 7 supplement the accuracies and RTs for each basic emotion, which were calculated as the averages across conditions. Regardless of groups, the results showed a consistent pattern in which the accuracies were highest for happiness and surprise, followed by sadness and anger, and lowest for disgust and fear. The RTs exhibited a similar pattern, with faster responses to happiness and surprise, and longer duration for disgust and fear. No significant group differences were observed, except for the accuracies in sadness ($t = 2.496$, $p = 0.017$) and surprise ($t = 2.258$, $p = 0.031$).

3.3. Relationships between FER and Social Adaptive Functions

The accuracy and RT in the uncovered-without-guide condition were selected as indexes of the FER. No significant relationships were observed between the FER and the total score of the VABS ($r = -0.150$, $p = 0.475$ for accuracy; $r = 0.142$, $p = 0.499$ for RT, see Table 8). Also, no significant relationships were found between the FER and the subscales of the VABS ($r = -0.186$, $p = 0.373$ for accuracy and interpersonal relationships; $r = 0.326$, $p = 0.112$ for RT and interpersonal relationships; $r = -0.063$, $p = 0.765$ for accuracy and play and leisure; $r = 0.061$, $p = 0.772$ for RT and play and leisure; $r = -0.154$, $p = 0.463$ for accuracy and coping skills; $r = -0.042$, $p = 0.844$ for RT and coping skills).

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Chapter 4 Discussions

This study aims to profile the FER performance for children with ASD and TD, investigate the effect of visual processing on FER in ASD, and establish the relationships between FER and social adaptive functions. Three main findings are as follows: (1) The ASD children performed worse than the TD children in the uncovered conditions. (2) The ASD children performed better in the uncovered conditions than in the covered conditions, and they did not improve FER performance after being guided. (3) No significant relationships were found between the FER and the VABS scores.

4.1. FER Performance of ASD and TD Children

Before discussing the group differences and within-ASD-group differences in the FER task, it is important to consider FER-related factors such as age, gender, and nonverbal intellectual abilities. Previous research suggests that FER skills in individuals with TD tend to develop with age, while impairments in FER in ASD persist, resulting in diverging developmental trajectories between the two populations (Chung et al., 2014; Lozier et al., 2014; Uljarevic & Hamilton, 2013). However, the results of this study, aligned with a cross-cultural study, reveal that individuals with ASD may also develop FER skills (Fridenson-Hayo et al., 2016). The surprisingly moderate correlation highlights the possibility that the FER impairments are not as remarkable as previously assumed. Children may naturally develop their FER skills while facing social relationships during their school years.

Regarding gender differences, results in this study did not replicate surpassing FER performance in TD girls compared to boys (Kuusikko et al., 2009). It is worth noting that younger children were included in our study. Gender differences may not be apparent at this age, as girls are generally perceived as more empathetic than boys

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starting from the adolescent period (Rochat, 2023). In the ASD group, the similar performance between genders suggests that being female may not overcome the challenges in FER faced by children with ASD. The social difficulties experienced by children with ASD are comprehensive and do not vary in gender.

Lastly, consistent with previous research, nonverbal intellectual abilities may not contribute to FER performance in either the ASD group or the TD group. In the ASD group, this finding suggests that FER difficulties are prevalent across individuals with different ASD diagnoses, including Asperger's syndrome, high-functioning autism (HFA), and typical ASD (Uljarevic & Hamilton, 2013). In the TD group, the results support the notion that nonverbal intellectual abilities, particularly deductive abilities assessed in this study, may not necessarily facilitate the use of more effective FER strategies.

In conclusion, children with ASD have the potential for improvement in FER during their school-age years, highlighting the importance of interventions targeting FER skills during this developmental period. The findings also indicate that FER performance does not differ based on gender and is independent of nonverbal intellectual abilities. This suggests that FER skills cannot be compensated by a higher intelligence or being female.

4.2. Effects of Visual Processing on the FER

The findings regarding accuracies demonstrate that visual processing patterns have an impact on FER. In the FER task, the uncovered-with-guide condition provides participants with full photographs and guidance to facilitate global processing, while the covered conditions require participants to rely on limited visual cues for local processing. The results indicating group differences in the uncovered-with-guide

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condition, but not in the covered conditions, suggest that individuals with ASD have difficulties in global processing. This finding can be explained by the WCC theory, which suggests that individuals with ASD may struggle to derive meaning from a configuration comprised of piecemeal figures, and this perceptual difficulty seems to extend to the process of FER. It can be inferred that the facial properties they perceived may not be well-organized, and they may approach FER by focusing on checking off specific facial features associated with a particular emotion, rather than perceiving the overall emotional expression. Consequently, their responses may reflect the number of features associated with the emotion rather than the overall emotional experience, making them appear unnatural when feeling others. Thus, it can be concluded that individuals with ASD may have difficulties effectively integrating facial information, aligning with their challenges related to WCC.

The within-ASD-group results showed superior performance in the uncovered conditions as compared to the covered conditions. Based on a previous study showing photographs wearing masks, it is certain that occluding a face hampers the FER performance since emotion is detected from multiple facial properties (Grahlow et al., 2022; Pazhoohi et al., 2021; Ramachandra & Longacre, 2022; Tso et al., 2022). If the EPF theory, which suggests a greater advantage in local processing compared to global processing, could be extended to explain the process of FER, similar performances in uncovered and covered conditions would be observed. However, the findings of this study revealed that children with ASD performed better in the uncovered conditions than in the covered conditions. This indicates that recognizing emotions based on limited facial properties poses a challenge. Facial features can exhibit substantial variability across different emotions. Despite individuals with ASD being perceived as having superior discrimination abilities, they are unable to effectively utilize these

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advantages in the context of FER. To attain better FER performance, exploiting information from attending to all the facial properties still might be the optimal strategy.

No significant differences were observed within the uncovered conditions. Similar performances in the uncovered conditions indicate that verbal guidance reminding participants to attend to all facial properties may not effectively promote global processing. Furthermore, the trend of increased RTs after receiving guidance supports the notion that utilizing global processing is more effortful for children with ASD. Despite being provided with global strategies, children with ASD were unable to improve their accuracies, indicating that their difficulty lies not in overlooking information but rather in effectively integrating it. The local precedence effect does not provide an explanation for FER.

The findings regarding RTs, which represent the FER process, revealed that ASD reacts at a similar speed to the TD group. This finding does not necessarily indicate comparable FER performance to children with TD as they had lower accuracies. The RTs only reflect the inefficiency of the FER process in children with ASD, and may not adequately discriminate the differences in FER between the ASD and the TD groups.

In summary, the results of this study support the hypothesis that FER difficulties in children with ASD can be explained by the WCC theory. The findings suggest that children with ASD may have the ability to attend to multiple facial properties but struggle to integrate this information to derive emotional meaning. As a result, they may develop adaptive strategies, such as relying more on local processing. These results do not support the EPF theory which suggests that individuals with ASD may have superior local processing, nor do they support the notion of a local precedence effect, where global processing is underused.

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4.3. Generalization to Social Adaptive Functions

No significant relationship was found between the FER indexes and the VABS scores. Contrary to our knowledge and assumptions, the FER could not explain social performance, including aspects of interpersonal relationships, play and leisure, and coping skills. The FER problems appear to be a distinct cognitive process separate from social deficits. However, it is important to note that the VABS is a caregiver-reported questionnaire, reflecting the perspective of parents rather than the true social performance of the children. Additionally, due to differences in personalities and family cultures, the behaviors described in certain items may not apply to every child in the family environment, potentially leading to an overall underestimation of scores and compromising the validity of their autonomous social performance.

It is worth mentioning that one of our participants with ASD stated, "I could roughly understand others' emotions, but I have no idea what to say to him/her" after completing the FER task. This statement suggests that not all social problems in individuals with ASD can be attributed solely to poorer FER skills. Some children's social difficulties may stem from higher-level cognitive processes like empathy and language expression. In future investigations of the relationship between FER and social performance in individuals with ASD, it would be important to consider potential mediating variables as well as alternative assessments, such as performance-based tests.

4.4. Clinical Implications

4.4.1. Establish Emotional Knowledge

The knowledge of emotions is a prerequisite skill for recognizing others' emotional states (Adolphs, 2002). Before the formal experiment in the FER task, participants were asked to explain "what does it mean to you?" for each emotion (happiness, sadness,

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anger, disgust, surprise, fear). The statements from normal populations revealed two common strategies in describing their knowledge of emotions: using synonyms or drawing from personal experiences. Participants often defined emotions using similar terms or shared how they experienced these emotions. For example, children described sadness as grief or expressed, "Sometimes it makes me feel like crying," while disgust was associated with dislike, hate, and statements like "I do not like some of my classmates." These findings align with the development of abstract categories, suggesting that children initially form a category based on an exemplar, such as tears representing sadness (Hoemann et al., 2019). As they gain more experience, they broaden their understanding of the category by recognizing similarities across situations or differences in related circumstances. They begin to realize that shedding tears is not a necessary condition for sadness and gradually develop more nuanced concepts within the category. Concurrently, they refine their language to label these nuanced characteristics, enabling them to differentiate subtle distinctions between feelings, such as unhappiness, sadness, grief, and heartbreak. So, integrating the perspective of abstract category development with our qualitative results, it can be suggested that emotional knowledge is rooted in language development and introspection of life experiences.

As children with ASD often face challenges in language and understanding emotions, their descriptions of emotional knowledge are often limited. For instance, they may simply describe happiness as "just happy" or make statements like "something good happens" without providing further details. In some cases, ASD participants even report that they do not understand emotions or rely on actions instead of verbal descriptions. As mentioned, language plays a crucial role in expressing personal feelings. Guiding children with ASD to expand their understanding of synonyms and

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encouraging reflection on when different emotions occur may enhance their emotional concepts and awareness of their feelings.

4.4.2. Connect Emotional Knowledge to A Face

In addition to exploring the meaning of emotions, participants in this study were also asked about their strategies for recognizing emotions, and their responses are listed in Appendix C. Overall, children with ASD reported a comparable number of facial characteristics compared to TD children, and their observations were mostly reasonable. When combining these findings with the quantitative results of the WCC and the EPF theories, it can be inferred that children with ASD can recognize emotional information conveyed through individual facial properties and attend to multiple properties. However, they may encounter difficulties integrating this information to derive emotional meaning. This process highlights the possibility that FER in children with ASD could be improved by maintaining strategies that focus on systematizing and facilitating the integration of information, which aligns with their strengths in local processing and challenges in global processing.

In the book by Ekman and Friesen (2003), emotions were deconstructed into various facial characteristics. For example, they proposed that happiness is primarily displayed in the lower face, with the nasolabial fold being one of the most noticeable signals. Fear can be exhibited through exposed sclera and gathered wrinkles in the center of the forehead. The idea of improving FER by understanding facial characteristics has been applied to individuals with ASD in a previous study. In that study, children with ASD were taught to identify specific components of facial expressions, such as the O-shaped mouth in surprise, before making judgments (Ryan & Charragáin, 2010). The results indicated significant improvements in FER after a four-

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week intervention, suggesting that children with ASD are capable of recognizing emotions through such strategies. This serves as a good example of combining local and global strategies, as children were encouraged to process the information they perceived, which may facilitate their integration of the information. As mentioned earlier, children with ASD may approach emotions by checking off specific facial properties associated with a particular emotion. It is possible that they could also benefit from being guided to check all the facial properties, such as examining lower lips pushing up the upper lips, wrinkled nose, and raised cheeks to infer disgust. Although this approach may not be natural, it maintains a focus on local processing while acknowledging that global processing is dominant in FER. This adaptive strategy may contribute to improved FER abilities.

In summary, the findings in this study have two important clinical implications for children with ASD. Firstly, expanding their knowledge of emotions can be achieved by familiarizing them with a variety of synonyms and encouraging reflection on personal experiences. Secondly, children with ASD may be able to observe and attend to multiple sources of information, but they may have difficulties integrating this information. Teaching specific facial characteristics and guiding them to systematically check off all relevant properties before making judgments may help maintain their inherent local processing style while simultaneously facilitating the use of global processing.

4.5. Limitations and Recommendations for Future Works

This study provides convincing results regarding FER in children with ASD. However, it is important to acknowledge several limitations related to emotional issues, task design, and participants' characteristics. Here we initiate a discussion regarding the boundary and nature of emotions in this study. It is worth noting that the primary aim of

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our study is to investigate the effect of visual processing on FER, rather than comprehensively profiling the performance for each specific emotion. Therefore, only basic emotions were included in the evaluation, limiting the generalizability of the results to more complex or mixed emotions, such as guilt, embarrassment, or jealousy. Additionally, the agreement of photographs depicting disgust and fear was inherently lower compared to other emotions （陳建中等，2013）, rendering it less meaningful to compare accuracy across different emotions. This discrepancy may stem from variations in expressing these emotions in photographs, or difficulties in distinguishing negative emotions due to shared features. Future studies should clarify the boundaries and nature of emotions.

The second limitation refers to the task design. First, The FER task only presented two options, which may have reduced sensitivity as participants could guess the answer with a minimum probability of fifty percent. This design may not fully reflect real-life FER performance, where individuals naturally experience and identify emotions without predetermined options. However, previous studies have indicated similar FER performance between labeling and matching tasks (Uljarevic & Hamilton, 2013), suggesting that the forced-choice design, which mitigates the influence of language development, may be more suitable for young or ASD children who may struggle to label emotions precisely. Another important issue is the lack of sufficient evidence regarding the participants' eye gaze patterns. Visual processing might be more understood by analyzing eye gaze positions rather than relying on assessment results. Therefore, direct observations of participants' eye gaze using eye-tracking techniques should be included, for example, comparing the differences in fixation time on different facial properties within the context of emotions. Still another issue is the content of the guide. To highlight the boundary of the whole face, participants were encouraged to notice the important

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facial properties. However, this could mislead the participants to systematize or scan over these properties, rather than truly process in configuration. A more valid strategy for global processing should be developed. The final limitation regarding task design is the insufficient evaluation of social performance. Only the parent-reported social adaptive functions could not represent the social performance. As mentioned, other aspects of social domains or other assessment methods should be considered in future studies.

Lastly, it is important to consider the confounding effect of participants' characteristics on FER results. Our recruitment revealed that nearly 80 percent of the ASD participants had comorbidities of ADD or ADHD. While we believe that local processing may not be overshadowed by ADHD traits, it is crucial to acknowledge that the FER performance, particularly RTs, may partly reflect the influence of ADHD rather than solely ASD traits. To gain a clearer understanding of the specific impact of visual processing on FER in ASD, future studies should consider excluding participants with ADHD or implementing assessments of attention such as SNAP-IV, to control for this confounding effect and clarify the unique contributions of ASD-related factors.

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Chapter 5 Conclusions

This study provides evidence that school-aged children with ASD are not skilled in FER compared to age-matched TD children. However, it was observed that accuracy in FER can improve with age. The WCC theory could explain the discrepancy between the two groups. Despite being prompted to attend to all facial properties, ASD children still struggle with integrating information. The EPF theory and the local precedence effect do not manifest in the FER process, as ASD individuals do not exhibit superiority in local processing nor show improvement after receiving global strategies. The generalization of FER skills to daily social performance is limited. Further investigation of this connection is warranted in future studies.

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Table 1. Demographic Information

	ASD (N = 25)	TD (N = 24)	p-value
Age, month (mean/SD)	115.60 (15.74)	113.58 (19.05)	0.688
Gender (N)			0.006*
Male	20	10	
Female	5	14	
ABCT, scores (mean/SD)	23.96 (9.93)	1.33 (2.22)	<0.001*
Sensory	3.84 (1.99)	0.21 (0.51)	<0.001*
Relating	6.00 (2.72)	0.25 (0.61)	<0.001*
Body and Object Use	6.00 (3.07)	0.54 (1.10)	<0.001*
Language	3.40 (2.40)	0.04 (0.20)	<0.001*
Social and Self Help	4.72 (2.05)	0.29 (0.55)	<0.001*
RPM, standardized scores (mean/SD)	102.60 (13.26)	111.58 (10.18)	0.011*
VABS, v-scores (mean/SD)	26.24 (7.63)	48.21 (7.32)	<0.001*
Interpersonal Relationships	7.72 (3.01)	16.63 (2.90)	<0.001*
Play and Leisure Time	9.28 (3.34)	15.83 (2.30)	<0.001*
Coping Skills	9.24 (2.42)	15.75 (2.97)	<0.001*

*: $p \leq 0.05$

ABCT: Autism Behavioral Checklist- Taiwan Version (ABCT)

RPM: Raven’s Progressive Matrices

VABS: Vineland Adaptive Behavior Scale 3

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Table 2. Between-Group Differences of the Accuracies in the FER Task

Conditions	ASD (N = 21) (percent, mean/SD)	TD (N = 22) (percent, mean/SD)	F	p-value	η^2_p	Simple comparison
	Group					
Uncovered						
without guide	84.31 (7.75)	88.66 (3.95)	6.037	0.018*	0.114	ASD<TD
with guide	84.80 (7.05)	88.80 (4.08)	5.829	0.020*	0.110	ASD<TD
Covered						
mask	80.31 (8.32)	82.59 (5.59)	1.260	0.267	0.026	ASD=TD
colored-glasses	79.73 (8.45)	82.41 (6.48)	1.539	0.221	0.032	ASD=TD

η^2_p: partial eta-squared

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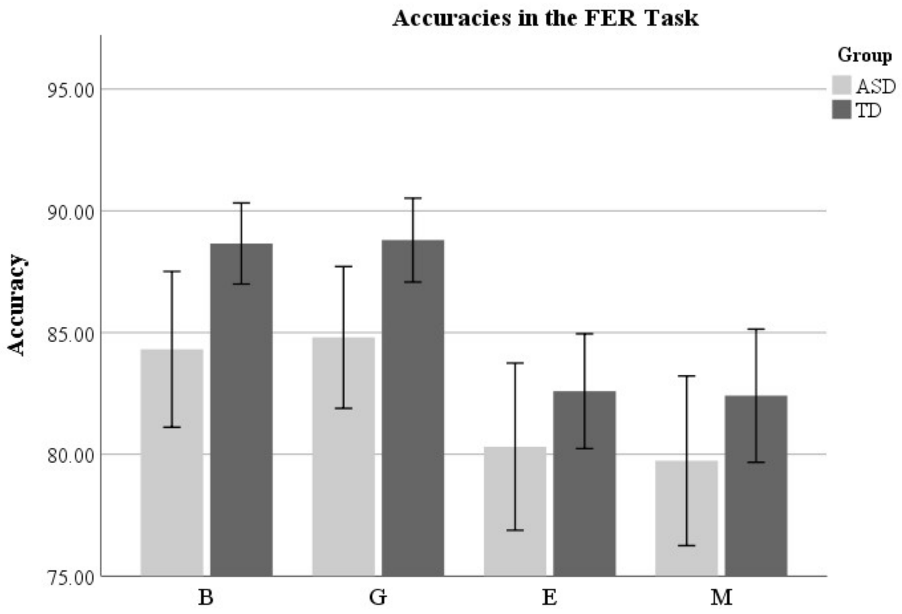
Figure 1. Bar Chart of Accuracies in the FER task



Unit of accuracies: percent

B: Uncovered-without-guide condition

G: Uncovered-with-guide condition

E: Covered-mask condition

M: Covered-colored-glasses condition

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Table 3. Between-Group Differences of the RTs in the FER Task

Conditions	Group: ASD (N = 21) (secs, mean/SD)	Group: TD (N = 22) (secs, mean/SD)	F	p-value	η^2_p
Uncovered					
without guide	1.14 (0.33)	1.41 (0.54)	4.094	0.050*	0.091
with guide	1.22 (0.39)	1.39 (0.47)	1.649	0.206	0.039
Covered					
mask	1.32 (0.47)	1.52 (0.56)	1.685	0.202	0.039
colored-glasses	1.23 (0.38)	1.41 (0.61)	1.402	0.243	0.033

*: $p \leq 0.05$

η^2_p: partial eta-squared

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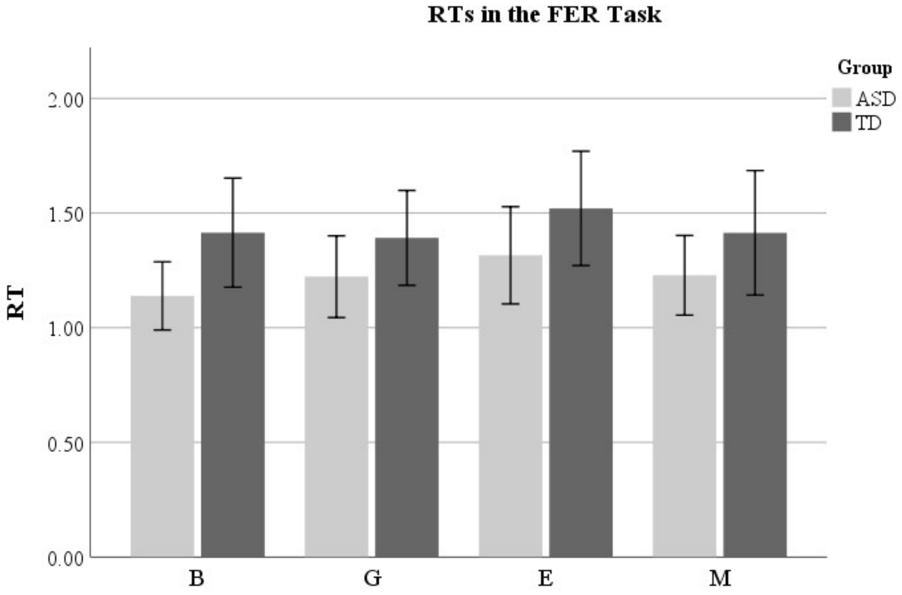
Figure 2. Bar Chart of RTs in the FER task



Unit of RT: second

B: Uncovered-without-guide condition

G: Uncovered-with-guide condition

E: Covered-mask condition

M: Covered-colored-glasses condition

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Table 4. Within-Group Differences of the Accuracies in the FER Task

	Uncovered Conditions		Covered Conditions		F	p-value	η^2_p	Simple Comparison
	without guide (percent, mean/SD)	with guide (percent, mean/SD)	Mask (percent, mean/SD)	colored glasses (percent, mean/SD)				
ASD	84.31 (7.75)	84.80 (7.05)	80.31 (8.32)	79.73 (8.45)	11.280	<0.001*	0.429	B=G>E=M
TD	88.66 (3.95)	88.80 (4.08)	82.59 (5.59)	82.41 (6.48)	20.273	<0.001*	0.575	B=G>E=M

*: $p \leq 0.05$

η^2_p: partial eta-squared

B: Uncovered-without-guide condition

G: Uncovered-with-guide condition

E: Covered-mask condition

M: Covered-colored-glasses condition

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Table 5. Within-Group Differences of the RTs in the FER Task

	Uncovered Conditions		Covered Conditions				
	without guide (secs, mean/SD)	with guide (secs, mean/SD)	Mask (secs, mean/SD)	colored glasses (secs, mean/SD)	F	p-value	η^2_p
ASD	1.14 (0.33)	1.22 (0.39)	1.32 (0.47)	1.23 (0.38)	1.359	0.270	0.095
TD	1.41 (0.54)	1.39 (0.47)	1.52 (0.56)	1.41 (0.61)	1.717	0.179	0.117

η^2_p: partial eta-squared

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Table 6. Accuracies in the FER Task across Emotion Categories

	ASD (percent, mean/SD)	TD (percent, mean/SD)	t	p-value
Happiness	92.93 (4.22)	95.07 (3.66)	1.887	0.065
Sadness	82.00 (9.25)	87.22 (4.78)	2.496	0.017*
Anger	81.73 (10.37)	85.14 (6.37)	1.391	0.172
Disgust	79.07 (9.31)	81.46 (5.90)	1.079	0.287
Surprise	89.73 (9.61)	94.44 (3.98)	2.258	0.031*
Fear	68.27 (9.62)	70.35 (8.31)	0.809	0.423

*: $p \leq 0.05$

Table 7. RTs in the FER Task across Emotion Categories

	ASD (secs, mean/SD)	TD (secs, mean/SD)	t	p-value
Happiness	0.92 (0.29)	0.92 (0.32)	-0.032	0.975
Sadness	1.26 (0.37)	1.52 (0.49)	1.913	0.063
Anger	1.21 (0.39)	1.40 (0.55)	1.306	0.199
Disgust	1.41 (0.45)	1.71 (0.72)	1.635	0.111
Surprise	0.97 (0.30)	1.07 (0.44)	0.939	0.353
Fear	1.59 (0.56)	2.00 (0.81)	1.892	0.066

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Table 8. Relationships between the FER Task and VABS in the ASD Group

	FER Accuracy	FER RT	VABS IR	VABS PL	VABS CS	VABS SZ
FER Accuracy	-	-	-	-	-	-
FER RT	-0.136 p = 0.517	-	-	-	-	-
VABS IR	-0.186 p = 0.373	0.326 p = 0.112	-	-	-	-
VABS PL	-0.063 p = 0.765	0.061 p = 0.772	0.623 p = 0.001	-	-	-
VABS CS	-0.154 p = 0.463	-0.042 p = 0.844	0.651 p < 0.001	0.637 p = 0.001	-	-
VABS SZ	-0.150 p = 0.475	0.142 p = 0.499	0.872 p < 0.001	0.884 p < 0.001	0.852* p < 0.001	-

*: $p \leq 0.05$

IR: Interpersonal Relationships subscale

PL: Play and Leisure subscale

CS: Coping Skills subscale

SZ: Socialization scale

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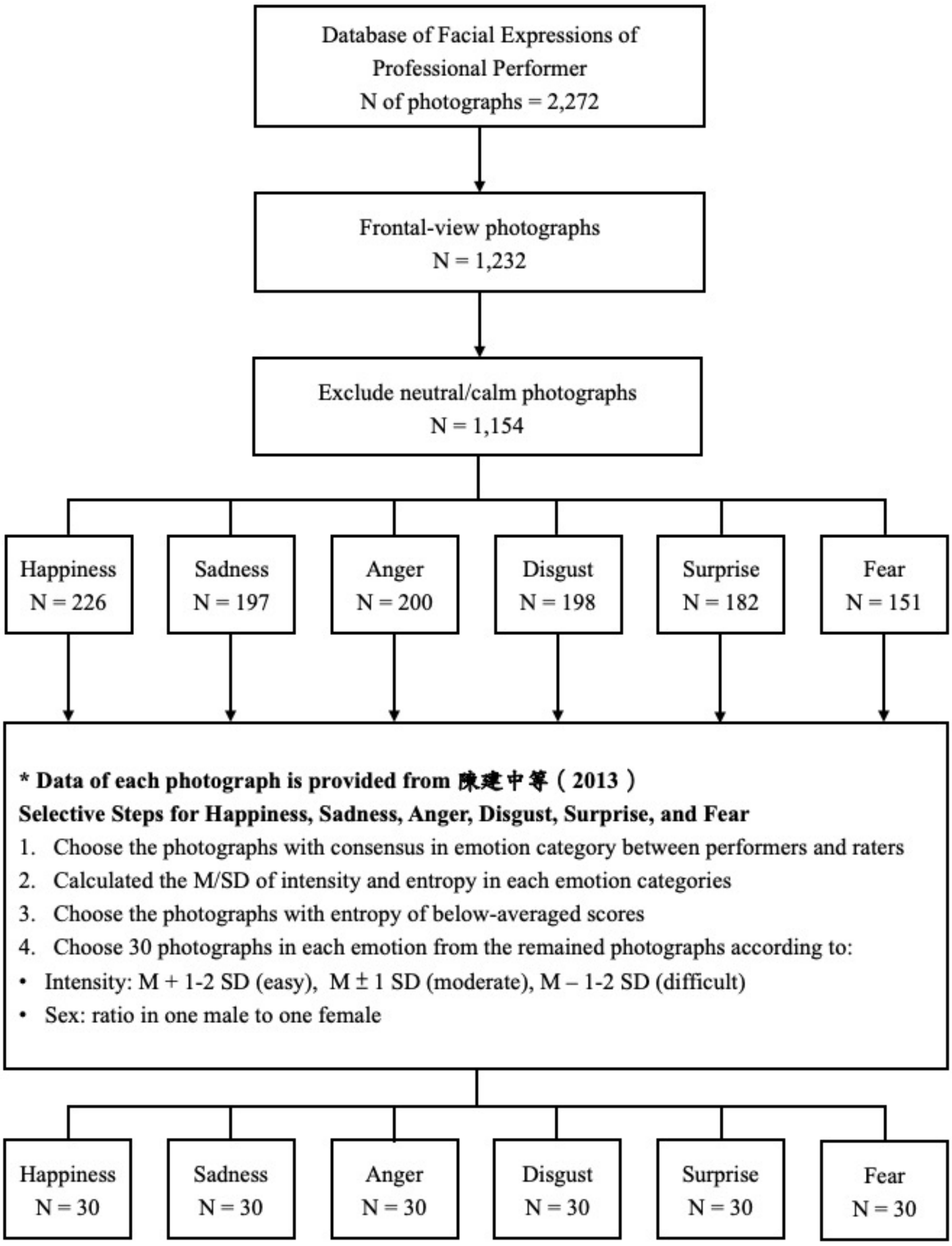
Appendix A



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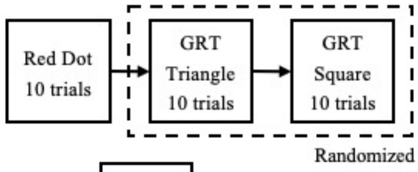
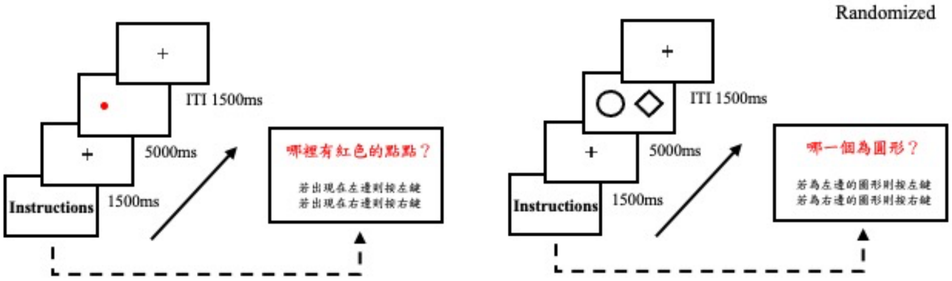
Appendix B

Practice Trials (30 trials)

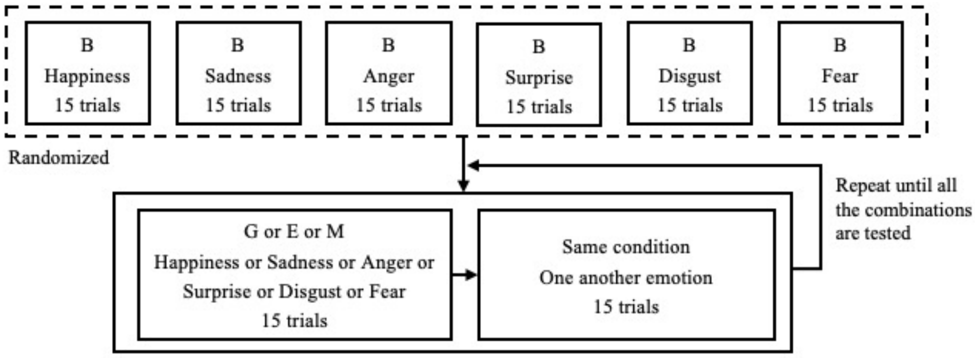
- Red Dot Task (10 trials)
- Geometric Recognition Task (GRT, 20 trials)

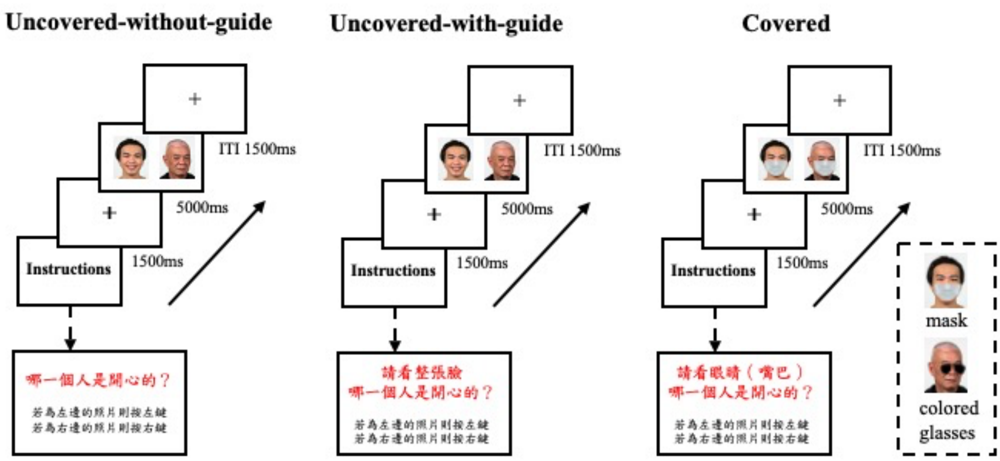




Formal Trials

- Uncovered-without-guide condition (B, 5 trials x 6 emotions x 3 intensities, 90 trials)
- Uncovered-with-guide condition (G, 5 trials x 6 emotions x 3 intensities, 90 trials)
- Covered-mask condition (E, 5 trials x 6 emotions x 3 intensities, 90 trials)
- Covered-colored-glasses condition (M, 5 trials x 6 emotions x 3 intensities, 90 trials)





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Appendix C

Emotion	**Facial properties**	**Participants' descriptions**
Happiness	Face/ Head	Raised cheeks
	Eyebrows	Elevated, curved, squinted, not-frowned
	Eyes	Downturned corners, wide-opened or squinted
	Nose	Lift-up
	Mouth	Upturned corners, smile, showing teeth
Sadness	Face/ Head	Downturned
	Eyebrows	Frowned, squinted
	Eyes	Downturned corners, red, with tears
	Nose	Not-reported
	Mouth	Closed or slightly opened, downturned corners, pout
Anger	Face/ Head	Twisted, tight
	Eyebrows	Frowned
	Eyes	Wide-opened, stared at someone
	Nose	Flare nostrils
	Mouth	Showing teeth, tight, pout, biting lips, closed
Disgust	Face/ Head	Tilt to other side, retract, twisted

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	Eyebrows	Curved, frowned
	Eyes	Looking elsewhere, squinted
	Nose	Not-reported
	Mouth	Downturned corners, pout, crooked
Surprise	Face/ Head	Not-reported
	Eyebrows	Elevated
	Eyes	Wide-opened, O-shaped
	Nose	Not-reported
	Mouth	Wide-opened, O-shaped
Fear	Face/ Head	Retract
	Eyebrows	Frowned, twisted, upturned corners,
	Eyes	Squinted, looking elsewhere (downside), wide-opened, with tears
	Nose	Not-reported
	Mouth	Pursed lips, downturned corners, wide-opened

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