From facial emotional recognition abilities to emotional attribution: A study in Down syndrome

Loyse Hippolyte[a], Koviljka Barisnikov[a], Martial Van der Linden [b], Jean-Jacques Detraux[c]

[a]*Child Clinical Neuropsychology Unit, University of Geneva, Boulevard du Pont d'Arve 40, 1211 Geneva 4, Switzerland*

[b]*Cognitive Psychopathology and Neuropsychology Unit, University of Geneva, Switzerland*

[c]*Psychology and Pedagogy of Disabled Person Unit, University of Liege, Belgium*

KEYWORDS: Down syndrome; Adult; Facial expressions; Emotional attribution

ABSTRACT

Facial expression processing and the attribution of facial emotions to a context were investigated in adults with Down syndrome (DS) in two experiments. Their performances were compared with those of a child control group matched for receptive vocabulary. The ability to process faces without emotional content was controlled for, and no differences appeared between the two groups. Specific impairments were found in the DS group according to the task modalities and the type of facial emotional expressions. In the emotion matching condition, the DS adults showed overall difficulties whereas in the identification and recognition conditions they were particularly impaired when processing the neutral expression. In the emotion attribution task, they exhibited difficulties with the sad expression only and the analysis of their error pattern revealed that they rarely selected this expression throughout the task. The sad emotion was the only one that showed a significant relationship with the facial expression processing tasks.

1. Introduction

People with Down syndrome (DS) have traditionally been characterized as friendly and very sociable (Carr, 1995; Dykens, Hodapp, & Evans, 1994; Gunn & Cuskelly, 1991). However, the recent literature emphasizes emotional and social behavioural problems in this population (Coe et al., 1999; Fidler, Most, & Philofsky, 2008; Jahromi, Gulsrud, & Kasari, 2008), yet the mechanisms underlying these difficulties remain relatively unexplored. The ability to lead successful social interactions can be seen as a complex process which relies on an intricate array of interacting cognitive, relational and emotional competences (Bach, Happe, Fleminger, & Powell, 2000; Carlson, Moses, & Hix, 1998). In particular, the ability to recognize facial emotional expressions and to

understand the emotional states of others are considered as skills central to develop and maintain adequate social relationships.

Studies investigating emotion processing in DS children generally reported difficulties with some specificities regarding the recognition of particular expressions. Some studies found impairments for the expressions of anger (Kasari, Freeman, & Hughes, 2001; Porter, Coltheart, & Langdon, 2007) and surprise (Wishart & Pitcairn, 2000), whereas several of them stressed difficulties with the recognition of fear (Kasari et al., 2001; Porter et al., 2007; Williams, Wishart, Pitcairn, & Willis, 2005; Wishart, Cebula, Willis, & Pitcairn, 2007; Wishart & Pitcairn, 2000). The error patterns in the emotional tasks have been investigated by few authors. Kasari et al. (2001) and Porter et al. (2007) reported a tendency to misidentify negative emotions as positive ones, which could not be repeated in Williams et al.'s (2005) or Wishart et al.'s (2007) studies. Despite the inconsistencies of the results, it emerges that the recognition of negative emotions is more problematic for DS children than that of positive ones. In fact, all studies reported their relative strength in processing the expression of joy. It is to be noted that the above studies concerned children and young adolescents with DS; the adult population was surprisingly left out. Yet, a large majority of these studies found that neither chronological age (CA) nor developmental age was related to better performances in the emotional tasks. In addition, Williams et al. (2005) observed that DS adolescents up to 17 years old did not outperform their younger peers, findings which suggested that adults and children with DS should present a similar response pattern.

In a recent study, Hippolyte, Barisnikov, and Van der Linden (2008) investigated facial emotion recognition in DS adults (CA = 33.3 years), whose results were compared with those of a control group composed of typically developing (TD) children matched for receptive vocabulary (EVIP-R, Dunn, Theriault-Whalen, & Dunn, 1993). The capacity to process facially expressed emotions was examined through three modalities: identification, matching and recognition. The emotion identification and matching tasks assessed the expressions of joy, sadness, anger and surprise. The recognition one assessed the expressions of joy, sadness and neutral, as well as the intensity attribution for joy and sadness. An additional task without emotional content (matching faces according to identity criteria) was administered to control for basic face processing skills. The main findings reported a specific impairment in the DS participants for the surprise expression (identification task) and the neutral expression (recognition task), while they did not differ from the control group in the face processing control task. Concerning the emotion matching task, Hippolyte et al. also reported that the DS adults performed, on the whole, poorer than their controls. Several facial expressions were significantly related to the receptive vocabulary measure, and this relation was

particularly strong with the neutral expression. When rating intensity, the DS adults showed a propensity to maximize the items of joy and minimize the items of sadness, while the investigation of their error patterns suggested the presence of a positive bias in judging facial stimuli. Some similarities appeared between the DS adult group's results and previous findings observed in DS children. Firstly, the DS adults did not differ from their control group in the task involving facial stimuli without emotional content, results which have also been found in several other studies (Williams et al., 2005; Wishart et al., 2007; Wishart & Pitcairn, 2000). In relation to the facial expression tasks, the difficulty to recognize the surprise expression had been observed by Wishart and Pitcairn (2000) as well, suggesting that the processing of this emotion did not improve with CA. Finally, the positive bias found in the DS adults' assessment of the facial stimuli might be related to the response pattern shown in children by Kasari et al. (2001) and Porter et al. (2007).

The aim of the present study was twofold. In Experiment 1, our objective was to replicate Hippolyte et al.'s previous study. No other studies had been published on emotion recognition abilities in the DS adult population, and our understanding of this issue remains limited. As such, some methodological modifications were introduced in their experimental design in order to increase the sensibility of the tasks (the addition of trials and distracters). In Experiment 2, the objective was to explore the DS adults' abilities to attribute a facial emotion to a social context. To our knowledge, these emotional attribution skills have never been investigated in this population, whereas we found only three studies exploring them in DS children. Each of these studies proposed a different experimental task. In Turk and Cornish's study (1998), the experimenter presented the participants with four drawings depicting a faceless figure in different social contexts (e.g., getting an ice-cream, being chased by a dog) and explained what was happening to the figure. Participants were then asked to point to the response card (four schematic drawings of the emotions of joy, sadness, anger and fear) which best suited the emotion experienced by the figure. For this task the DS children obtained a poorer global performance than that of the control group (children matched on the EVIP-R vocabulary scale). In Wishart and Pitcairn's study (2000), participants had to choose from three photographs of the same individual portraying different emotions (photos taken from Ekman & Friesen, 1976) the photo that corresponded to a brief verbal story told by the experimenter (e.g., receiving a present). Six items assessing the emotions of joy, surprise, sadness, fear and disgust were proposed in this task. The DS children obtained a lower global score than that of their control group (children matched on the basis of performance on the Kaufman Facial Recognition subtest, Kaufman & Kaufman, 1983), but this difference remained non-significant. Finally, Kasari et al. (2001) examined emotion attribution abilities through

a puppet paradigm in which the emotional situations were acted out by a puppet that had an expressionless face (e.g., puppet is taken to zoo by mother). The emotions of joy, sadness, anger, and fear were assessed (two items per emotion), but Kasari et al. did not specify how participants' responses were gathered. A series of three experiments were presented. In the first one, the results of the DS children did not differ from those of TD children matched for mental age (Standford-Binet Intelligence Scale, Thorndike, Hagen, & Sattler, 1986). In the second, the DS group performed significantly poorer on the items of anger and fear than their two control groups (TD children and children with ID of unknown aetiology). The third experiment tracked the progress of the DS children who had participated in Experiments 1 and 2 over a 2-year period, but no significant improvements were observed in the attribution task.

The findings of the above studies tend to show that DS children have global difficulties in attributing facial emotion according to a context. However, the variety of the situations proposed (drawing, story, scenario enacted) makes it difficult to infer a reliable response profile from these results. In addition, the limited number of items (one or two per emotion) used in these studies restrict the significance of their results and impede the possibility to pursue separate analyses per emotion. Finally, we do not know if the participants' abilities to recognize the emotions to be attributed were controlled for. This issue might be problematic as these abilities constitute a prerequisite to solve the attribution task. Moreover, the children in these studies were generally impaired in the other emotion processing tasks they were presented. As these studies did not report results from correlation analyses between these two types of tasks, we have no information at our disposal about this point.

The task we proposed in Experiment 2 was specifically created for people with mild to moderate intellectual disability (ID). The task instructions were short and simple to avoid additional information processing loads, and the responses did not require a verbal answer. The emotions of joy, sadness, anger and fear were assessed by means of four to five items per emotion. Finally, in our study we examined the relationships between the facial expression tasks presented in Experiment 1 and the emotion attribution task presented in Experiment 2. In addition, relations between these experimental tasks and specific cognitive competences were investigated. The DS adults' results were compared to those of TD children matched on receptive vocabulary, a matching measure which is frequently chosen in studies on emotion processing in people with ID (Bieberich & Morgan, 2004; Hippolyte et al., 2008; Turk & Cornish, 1998).

2. **Experiment 1**

In Experiment 1, we aimed to further explore the DS adults' abilities to process facial expressions by following Hippolyte et al.'s previous work. We therefore replicated their experimental design in order to see if similar results could be obtained. We also wanted to further examine the processing of the neutral expressions for which very impaired recognition was found in the DS adults group. New items for this expression were introduced in the identification and matching conditions allowing a more in-depth investigation.

2.1. METHOD

2.1.1. Participants

Twenty-four adults with DS took part in the study (17 men, 7 women), all with a moderate ID. All participants had a medical diagnosis of Trisomy 21 and were recruited from a sheltered workshop. DS adults with significant sensory, psychiatric or physical disabilities, as well as clinical symptoms of dementia were excluded from participation. The mean age of this group was 34.3 years (SD = 7.1). The adults were individually matched on gender and receptive vocabulary level (raw score) with a control group comprised of 24 TD children attending an elementary public school (mean age = 5.9, *SD* = 1.6). The receptive vocabulary task was the French adaptation (EVIP-R, Dunn et al., 1993) of the Peabody Picture Vocabulary Test-Revised (Dunn & Dunn, 1981). A Student t-test confirmed that no significant differences appeared between the two groups on this matching measure, $t(46) = -.186$, $p = .85$.

Two selective attention subtests (Rabbits and Faces) taken from the neuropsychological battery Nepsy (Korkman, Kirk, & Kemp, 2003) were administered to all participants in order to check for its potential influence on the experimental tasks (see Table 1). In the first subtest Rabbits, participants were asked to search for target pictures (rabbits) among dissimilar distracters (e.g., apple, tree, and dog). The second subtest Faces was more complex as two targets (two specific faces) had to be found among similar distracters (other faces). The time was limited to 180 s for each subtest, and participants were instructed to proceed as quickly as possible. The two groups did not significantly differ on the precision score (number of hits minus false alarms) for both subtests (Rabbits: $p = .061$, Faces: $p = .092$), but the DS adults took significantly more time to achieve them (Rabbits: $p = .002$, Faces: $p = .028$). The correlations between these two subtests were highly significant and the precision score for the Faces subtest only was kept so as to not enlarge the subsequent analyses (Rabbit subtest was realized near the ceiling by the two groups). Finally a non-verbal reasoning task was administered to the DS adults (Raven's Coloured Progressive Matrices, CPM, Raven,

Court, & Raven, 1998). They obtained a mean raw score of 16.08 (SD = 5.27), corresponding approximately to an IQ of 60.

2.1.2. Procedure and materials

The capacity to process facial expressions was examined through three types of tasks (expression identification, expression matching and facial discrimination), while the ability to process faces without emotional content was assessed through the identity matching test. All stimuli were monochrome photographs of children's faces, with the exception of the facial discrimination task which presented adults' faces (see Hippolyte et al., 2008 for details). These tasks were administered in a counterbalanced order and two to four sessions were necessary (25-35 min each) to complete them depending on the participants' fatigue and motivation. These sessions took place over approximately one to 2 weeks. All participants were tested individually in a quiet room at their workplace or at school. The research was approved by the Ethics Committee of the University of Geneva and authorisations from the institution, the legal tutors of the DS adults, and the school were obtained. Participants gave their oral consent to take part to the study, and were free to withdraw from the procedure at any time.

Table 1

Participants' mean results for the receptive vocabulary task (developmental age) and the Nepsy selective attention subtests, Rabbits and Faces (precision scores and time response).

	Receptive vocabulary		Selective attention							
			Rabbits				Faces			
	Mean	(SD)	Precision[a]		Time		Precision[a]		Time	
			Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
DS	6;5	(2;8)	17.8	(3)	112.1[a]	(43.6)	4.1	(7.8)	170.7[c]	(20.2)
Control	6;6	(2;3)	19	(1.3)	75.9[b]	(31.2)	8.2	(8.4)	148.5[d]	(43.4)

Note: a > b, $p < .01$; c > d, $p < .05$.

[a] Maximum precision score = 20 for each subtest.

2.1.2.1. *Identity matching test.* The identity matching test assessed the ability to match faces on the basis of their identity, and was used in this experiment as a control measure for basic face processing skills. This task, originally taken from the battery Face Processing Tests (Bruce et al., 2000), was composed of five subtests of increasing difficulty. The subtests 1, New Face-Dis and 2, New Face-Sim constituted adapted versions (respectively called Face-Dis and Face-Sim in Bruce et al.'s battery) to which a second distracter had been added, whereas the subtests 3-5 had not been modified. Each of these five subtests consisted of 16 items and had a similar design: a

target face was shown at the top of the page and participants had to identify the target face (out of three faces for subtests 1 and 2 and out of two faces for subtests 3-5) at the bottom of the page. One trial item was offered for the first three subtests to ensure comprehension of the task.

The first two subtests New Face-Dis and New Face-Sim presented complete faces with distracters respectively dissimilar and similar (same versus different gender, age and general appearance). The subtest 3, Maskedface-Dis, and 4, Maskedface-Sim, presented faces that were dissimilar/similar, respectively, with the hair and ears concealed. The subtest 5, Eyesmasked-Sim, presented similar faces with hair, ears, and eyes concealed. The last three subtests were processed with difficulty by all participants in Hippolyte et al.'s study, and rough difficulty in Bruce et al.'s (2000) study, which showed that the success rates were not above the level of chance before the age of 7 or 8 for the subtests 4 and 5. These last three subtests were assessed in this experiment to see if Hippolyte et al.'s previous results could be replicated.

2.1.2.2. *Expression identification and expression matching tasks.* The expression identification and the expression matching tasks were adapted from two tests of the Bruce et al.'s battery (respectively called Emotion-Id and Emotion-Match). The number of the distracters had been increased (two instead of one in the original version) and a new expression (neutral) had been inserted. For the expression identification task which was found easier to execute than the expression matching task in Hippolyte et al.'s study, an additional item per facial expression had been added to increase the task demand. Both tasks assessed five facial expressions: joy, sadness, anger, surprise and neutral.

In the expression identification task (20 items) participants were shown the stimuli of three faces which were placed next to another, and had to point to the face that displayed a particular emotion named orally by the experimenter (4 items per expression). In the expression matching task (15 items), a target face was shown at the top of the page and the participants were asked to point to the face at the bottom (out of three) that displayed the same expression as the top one (3 items per expression). One trial item was administered in this task.

2.1.2.3. *Facial discrimination task.* The facial discrimination task (Rojahn, Rabold, & Schneider, 1995) assessed facial expression recognition and emotion intensity attribution. It consisted of 41 photographs presenting three expressions: happy, sad, and neutral. The participants had to indicate whether a given item depicted a happy face, a sad face, or a face that was neither happy nor sad (neutral). If the response was happy (or sad), they were asked to decide between two

intensity levels for that emotion. Level 1 was for a face that was 'a little' happy or sad and level 2 for a face that was 'a lot' happy or sad. Participants had a training session with 6 items, before performing a test which consisted of randomly presenting 12 happy faces (9 for the first level, 3 for the second), 12 neutral faces and 11 sad faces (7 for the first level, 4 for the second). In addition, an emotional bias score reflecting error size and trend (overly positive versus negative responses) could be computed for this task. This measure was obtained by calculating an error ranking for each response (plus one point per degree in the positive trend and minus one point per degree in the negative trend). For example a 1- point positive score was assigned when the participant said 'very happy' instead of 'a little happy'.

2.2. Results

The assumption of a normal distribution using one-sample Kolmogorov-Smirnov tests was tested for all experimental tasks variables (separately for each group). A normal distribution was found for the identity matching test and the facial discrimination task allowing us to conduct parametric analyses. Some of the variables of the two facial expression tasks expression identification and expression matching did not follow a normal distribution, and non-parametric analyses were run for these tasks.

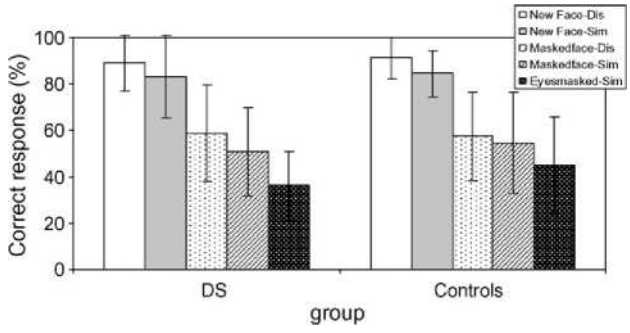

Fig. 1. *Mean percentage of correct responses in each of the five identity matching subtests for the two groups.*

2.2.1. Identity matching test

The identity matching test data were analysed by means of a 2 (group) x 5 (task) repeated- measure ANOVA. Fig. 1 illustrates percentage scores (per group) for the five subtests. There was a significant main effect of task, $F(4,176) = 91.75$, $p < .0001$, $\eta^2 = .675$, but no effects of group, $F(1,44) = .69$, $p = .41$, $\eta^2 = .015$, nor interaction, $F(4,176) = .07$, $p = .58$, $\eta^2 = .015$. Subsequent Bonferroni post hoc comparisons showed that the first two

subtests New Face-Dis and New Face-Sim presenting complete faces were equally well realized by the two groups, and significantly better than the three subtests Maskedface-Dis, Maskedface-Sim, and Eyesmasked-Sim.

2.2.2. Expression identification and expression matching tasks

Table 2 presents the main results for the expression identification and expression matching tasks, as well as the outcomes of the statistical inter-group analysis (Mann-Whitney *U* tests). In the expression identification task, the DS group's performances were significantly lower than these of the control group for all expressions, except sadness. Intra-group analyses were pursued using Wilcoxon signed-rank test. In the DS group, expressions of joy and anger were significantly better recognized than the expressions of sadness (ps < .01), surprise (ps < .02), and neutral (ps < .001). Whereas no significant differences appeared between the expressions of sadness and surprise, the neutral expression was the worst recognized (ps < .01). In the control group, the score for the emotion of sadness was significantly poorer than the scores for the emotions of joy (p = .005), anger (p = .001) and surprise (p = .037).

Table 2

Mean raw scores of the two groups on the expression identification and expression matching tasks.

Tasks	Max. score	DS		Controls		Mann-Whitney	
		Mean	(SD)	Mean	(*SD*)	*U*	*p*
Expression identification							
Joy	4	3.29	(.99)	3.79	(.41)	206	.042
Sadness	4	2.42	(1.24)	2.88	(1.22)	227	.192
Anger	4	3.38	(.82)	3.96	(.20)	166.5	.001
Surprise	4	2.63	(1.34)	3.5	(.93)	180	.015
Neutral	4	1.63	(.82)	2.92	(1.13)	116	.000
Expression matching							
Joy	3	1.87	(.75)	2.75	(.44)	105	.000
Sadness	3	1.43	(1.08)	2.63	(.64)	103	.000
Anger	3	1.3	(1.10)	2.42	(.71)	122	.001
Surprise	3	1.35	(.88)	1.75	(.84)	211	.136
Neutral	3	1.17	(.98)	2.17	(.86)	128	.001

Relating to the expression matching task, Mann-Whitney analyses showed that the DS adults obtained significantly lower scores than their controls for all expressions, except surprise. The main results for the intra-group analyses revealed that the expression of joy was significantly better recognized by the DS participants than neutral (p = .006) and surprise (p = .043). No significant differences appeared between the other four expressions. In the control group, the expressions of joy and sadness were significantly better processed than the expressions of surprise (ps < .001) and neutral (ps < .01).

2.2.3. Facial discrimination task

A 2 (group) x 3 (expression) repeated-measure ANOVA was first conducted, taking into account the scores (percentages) for the happy, sad and neutral expressions (see Fig. 2). The analysis revealed that there were significant main effects of group, $F(1,46) = 29.37$, $p < .0001$, $\eta^2 = .394$ and expression, $F(2,90) = 9.64$, $p < .001$, $\eta^2 = .197$. A significant interaction between expression and group, $F(2,90) = 12.87$, $p < .0001$, $\eta^2 = .211$, was also observed. Bonferroni post hoc comparisons revealed that the DS adults recognized fewer neutral items than their controls, $p < .0001$. The DS group identified both sad and happy expressions (ps < .0001) more easily than the neutral ones, while no significant differences appeared between the three expressions for the control group.

A 2 (group) x 2 (emotion) x 2 (intensity) repeated-measure ANOVA was then performed to determine whether groups differed when rating the emotional intensity of the sad and happy emotions. The analyses revealed two significant main effects: group, $F(1,45) = 17.99$, $p < .001$, $\eta^2 = .285$, and intensity, $F(1,45) = 51.11$, $p < .0001$, $\eta^2 = .531$. There was no significant interaction between group and emotion (p = .13), and group and intensity (p = .14), but there was a marginal effect of the triple interaction group x emotion x intensity, $F(1,45) = 3.21$, $p = .079$, $\eta^2 = .066$. Post hoc Bonferroni tests showed that the DS group identified the very happy faces significantly better than all the other expressions (ps < .05). The faces with very sad expressions were better recognized than ones with little happy expressions (p < .001). No differences were found between the recognition of little and very sad expressions (p = .254). The control group showed a similar pattern, but their results did not differ between the very happy and very sad faces (p = .98), which were similarly recognized.

Finally, we analysed the error pattern of the two groups by carrying out an analogous error analysis like the one proposed in Hippolyte et al.'s study. We observed that the large majority of the participants rarely selected an emotion in the opposite hedonic tone (e.g., happy for sad) when they gave an incorrect answer. We also noticed that the DS group tended to propose the emotion of joy more often than the emotion of sadness and instead of the neutral expression. Participants with DS obtained an emotional bias

mean score of 11.95 (*SD* = 14.5) which was significantly greater than the one obtained by their controls (score = 2.29, *SD* = 4.34) (*t* = 3.11, *p* = .003).

2.2.4. Correlations between the three facial expression tasks, CA, and cognitive tasks

A series of correlations were run to investigate the relationships between the three facial expression tasks, CA and the cognitive tasks. Significant relations appeared in the DS group with all the cognitive tasks (see Table 3), but the most significant among them was found with the receptive vocabulary measure, which was related to several expressions within the three tasks. More particularly, a strong relation was found in the facial discrimination task with the neutral expression (r = .66, *p* = .001). The non-verbal reasoning score and the selective attention measure were related to the expression identification and expression matching task to a lesser extent.

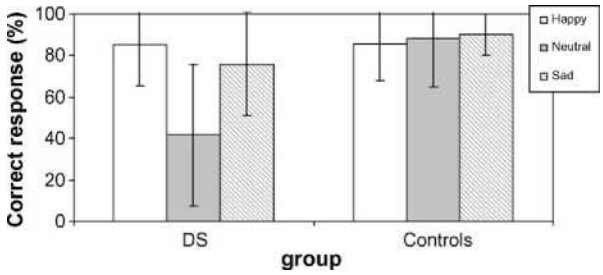

Fig. 2. *Mean percentage of correct responses (per expression) in the facial discrimination task for the two groups.*

In the control group, we observed that CA was strongly related to cognitive measures; full and partial correlations were therefore run controlling for CA. The main results showed that the expression of sadness was related to CA in the three facial expression tasks (Identification: t =.38, *p* = .018; Matching: t = .49, *p* = .004; Discrimination: *r* = .42, *p* = .034). For the expression matching task, CA was also related to surprise (t = .32, *p* = .046) and neutral (t = .42, *p* = .009). The significant relations observed between the facial expression tasks and the EVIP-R score were not preserved after controlling for CA. For the selective attention measure, a significant relation remained with the neutral expression score in the expression matching task (*r* = .53, *p* = .008).

Table 3 - Correlations between the expression identification and expression matching tasks (Tau-B), facial discrimination task (Pearson), chronological age and cognitive measures in the DS group.
*p < .05. **p < .01.

Variables	CA	EVIP-R	Nepsy Faces	CPM Raven
Expression identification				
Joy	.03	.29	.28	.36*
Sadness	.30	.26	.15	.25
Anger	-.06	.35*	.18	.47**
Surprise	.12	.44*	.45**	.38*
Neutral	.21	.17	.14	.25
Expression matching				
Joy	-.23	.06	.24	.06
Sadness	-.04	.33*	.26	.24
Anger	-.23	.06	.22	.16
Surprise	-.33	.38*	.24	.32
Neutral	-.09	.34*	.37*	.33*
Facial discrimination				
Joy	.23	.25	.01	.13
Sadness	-.06	-.15	.08	-.03
Neutral	-.15	.66**	.21	-.35
Bias	.27	.01	.03	.28

2.3. Discussion

In Experiment 1, we examined the capacity to process facially expressed emotions through three modalities, namely identification, matching and recognition. The ability

to process faces without emotional content was controlled for, and no differences appeared between the two groups in this task. With regard to the facial expression tasks, we noticed important differences in the DS adults' performances depending on the task modality. They were very impaired in the matching condition, whereas they exhibited rather specific difficulties in the identification and recognition task according to the expressions.

Corroborating Hippolyte et al.'s previous findings, the DS group processed the neutral expression very poorly. In addition, the analysis of their response pattern in the recognition task showed a tendency to assess expressions as being more positive than they actually were. The correlational analyses stressed that in the DS group a particular implication of receptive vocabulary skills was involved in the processing of several expressions. The non-verbal reasoning and selective attention abilities were also related to certain expressions, often together with the vocabulary score.

3. **Experiment 2**

The main objective of Experiment 2 was to explore the DS adults' ability to attribute a facial emotion to a context, since to our knowledge this issue has never been examined with this particular population. For this purpose, we used a new task specifically created for people with mild to moderate ID. Furthermore, we aimed at investigating the relationships between these emotion attribution skills and the emotion processing abilities assessed in Experiment 1. We were also interested in the relations between the attribution task and specific cognitive competences.

3.1. Method

3.1.1. Participants

Each of the participants in Experiment 2 had been recruited for Experiment 1. However, three of the adults with DS did not participate in Experiment 2. The two groups of participants in this experiment consisted thus of 21 adults with DS (15 men, 6 women) and 24 TD children (17 boys, 7 girls). The mean age of the DS group was 34.7 years (SD = 7.4) and they had a developmental age of 6.6 (SD = 2.7) on the EVIP-R vocabulary matching measure. For the Nepsy selective attention subtests, their precision score was of 17.62 (SD = 3.18) for the Rabbits (mean response time = 116.05, *SD* = 42.29) and 4.33 for the Faces (SD = 7.9) (mean response time = 172.71, *SD* = 16.62). As with Experiment 1, the two groups did not significantly differ on the precision score for both Nepsy

subtests, and the DS adults took significantly more time to achieve them (Rabbits: p = .001, Faces: p = .017). The Faces precision score was kept as well for the subsequent statistical analyses. Finally, the DS group's raw score was of 15.9 (SD = 5.44) on the Raven CPM task.

3.1.2. Procedure and materials

The experimental task presented in Experiment 2 was administered in one session (15-25 min). All participants had been assessed with the EVIP-R, the Nepsy selective attention subtests, and the face processing and facial expression tasks (plus Raven CPM for the DS adults) during Experiment 1.

3.1.2.1. *The emotion attribution task.* The emotion attribution task (Barisnikov, Van der Linden, & Catale, 2004) assessed the ability to infer another's feelings according to a context. Specifically developed for people with mild to moderate ID, it consisted of pictorial material which was simple and easy to handle. Short and explicit instructions were given in order to reduce additional information processing loads, and no oral answers were needed to process the task.

The task was composed of 22 coloured drawings (13 cm x 18 cm x 3 mm) presented in two parts. Part 1 illustrated a young woman (Natacha, 10 items) and part 2 a boy (Marco, 12 items) in their daily social interactions. Each situation underlined a particular feeling: four items arouse the emotion of joy (e.g., opening Christmas presents), five items sadness (e.g., seeing a wounded bird lying on the ground), five items anger (e.g., being splashed with water by a car), and five items fear (e.g., encountering a threatening dog). In all drawings, the main figure's feelings were hidden as her/his face was missing (hole of approximately 3 cm x 3 cm x 3 mm). For each figure, five facial expressions (joy, anger, sadness, fear and neutral) were represented on little squares which fitted into the drawings.

The participant was introduced to the first part of the task by the experimenter, ‘‘I will show you some pictures about a girl called Natacha. You will see, many events happen to her’’. The instructions were then given, ‘‘The pictures I am going to show you are incomplete, Natacha's face is missing. You will have to add it, each time choosing from three faces. You will have to take the face which corresponds best to how Natacha feels in this situation’’. The five squares representing the above expressions were then presented to the participant one at a time. The experimenter made sure that the participant was able to recognize each of the expressions before introducing the first situation. The testing began with two learning trial items. The experimenter showed the drawing, and gave the instructions, ‘‘Look closely at this picture. From these three faces, pick out the one that best shows how Natacha feels in this situation. Once you

have decided, you can place it here''. The experimenter pointed at the hole where the face was missing. For the first two trial items, the experimenter corrected the answer if wrong, and a reflection was made together with the participant to find out the correct answer. After the trial items the responses were no longer corrected. This procedure was adopted in order to familiarize the participant with the different facial expressions and the task. The second part of the task relating to Marco's items was then presented. It followed the same procedure as for Natacha, but there was just one trial item and the five faces were proposed each time. Global scores could be calculated (maximum score = 19, part 1=8 points, part 2 = 11 points), as well as subscores for each emotional expression.

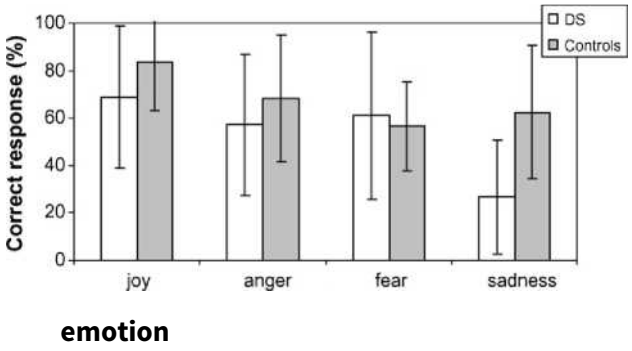

Fig. 3. *Mean percentage of correct responses for the four emotions of the emotion attribution task for the two groups.*

3.2. Results

3.2.1. Emotion attribution task

We first checked for both groups separately to establish if there were significant differences between the scores for Natacha's and Marco's parts. The differences remained non-significant (ps < .05) and subsequent analyses were performed by merging the two parts of the task. A 2 (group) x 4 (emotion) repeated-measure ANOVA was conducted to determine whether the groups differed on the attribution of the expressions of joy, anger, fear and sadness (scores in percentages) (see Fig. 3). The analysis revealed main effects of group, $F(1,43) = 8.43$, $p = .006$, $\eta^2 = .164$ and emotion, $F(3,129) = 12.06$, $p < .0001$, $\eta^2 = .219$. A significant interaction between emotion and group, $F(3,129) = 4.86$, $p = .003$, $\eta^2 = .101$, was also observed.

Bonferroni post hoc comparisons showed that the two groups only differed for the sad emotion, which was poorly attributed by the DS group ($p < .001$). The DS adults' score

for this emotion was significantly lower than the scores for the others expressions (joy: $p < .001$, anger: $p = .003$, fear: $p < .001$). In the control group, no significant differences appeared between the emotions of joy, sadness and anger, whereas the emotion of fear was more poorly attributed than the emotion of joy *(p* = .009).

3.2.2. Error analysis

The confusions committed by the two groups in the emotion attribution task were then investigated and Table 4 presents the percentages of responses (correct and incorrect) for each emotion that had to be attributed. The DS group's error pattern revealed specificities and not an overall error spread across all expressions. As with the control group, the DS adults mainly confused emotions of similar valence (e.g., anger instead of sadness). However, this was not the case for the emotion of sadness, which they frequently substituted with the emotion of joy. The error rates (percentages) for each emotion were then compared between the two groups (see Fig. 4) using Student t-tests analyses.

Table 4

Emotional expressions given by groups for the emotion attribution task (percentage).

Responses(%)	Expected answers							
	Joy		Anger		Fear		Sadness	
	DS	Controls	DS	Controls	DS	Controls	DS	Controls
Joy	**69**	**83**	11	3	11	8	31	12
Anger	7	3	**57**	**68**	16	15	14	12
Fear	8	4	12	4	**61**	**57**	12	6
Sadness	0	3	9	24	5	12	**27**	**63**
Neutral	15	6	10	1	7	8	15	8

Note: Bold type indicates correct responses; normal type indicates incorrect responses.

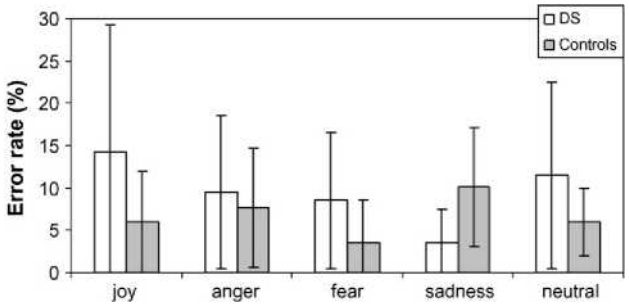

Fig. 4. *Mean percentage of error rate for the five expressions of the emotion attribution task for the two groups.*

The DS group showed significantly greater error rates than their controls for the expression of joy ($p = .03$) and fear ($p = .018$), whereas no differences appeared between the two groups for neutral ($p = .105$) and anger ($p = .461$) expressions. Of interest, the error rate for sadness was larger in the control group ($p = .001$). Intra-group analyses showed that this error rate was smaller than any of the other expressions ($ps < .02$) in the DS group, whereas no other significant differences were observed between joy, fear, anger and neutral.

3.2.3. Correlations between the emotion attribution task, cognitive and facial expression processing measures, and CA

Pearson's correlations were run within the two groups to investigate the relationships between the emotion attribution task (separately per emotion), the cognitive measures, the expression tasks (global scores) presented in Experiment 1, and CA (see Table 5). The CA was again controlled for in the children's control group, and partial correlations are presented in parentheses in Table 5.

In the DS group, few significant correlations appeared between the specific cognitive competences and the emotion attribution task. The only relations we observed were between the selective attention measure and the score for anger and sadness. Neither the measures of receptive vocabulary nor nonverbal reasoning were related to the various expressions of the Emotion Attribution task in this group. Furthermore, few relations were found with the facial expression tasks. The sad expression alone was significantly correlated to the expression identification and expression matching tasks.

In the control group, few relations appeared with the cognitive measures and the emotion attribution task; the sad emotion alone was related to both selective attention measure and receptive vocabulary. In contrast to the DS group, no significant relations appeared with the facial expression tasks assessed in Experiment 1. Finally, we

observed that CA was only related to the expression of anger.

Table 5

Correlations between the emotion attribution task, the expression identification and expression matching tasks, cognitive measures and CA in the DS and control groups.

Variables	Emotion attribution task				
	Groups	Joy	Anger	Fear	Sadness
CA	DS	-.02	-.40	-.11	-.40
	Controls	.34	.41*	.29	-.003
EVIP-R	DS	-.01	.28	.41	.34
	Controls	.38 (.19)	.43* (.19)	.30 (.11)	.30
Nepsy Faces	DS	.29	.50*	.31	.65**
	Controls	.37 (.24)	.26 (.08)	.36 (.26)	.46*
Expression identification	DS	.17	.31	.13	.47*
	Controls	.04 (-.12)	.40 (.27)	.13 (.01)	.18 (.19)
Expression matching	DS	.14	.23	.11	.75**
	Controls	.34 (.16)	.26 (-.01)	.11 (-.11)	.23 (.31)
Facial discrimination	DS	.25	.13	.16	.29
	Controls	.03 (-.07)	-.15 (-.31)	.06 (-.03)	.30 (.31)
CPM Raven	DS	.20	.32	.31	.41
	Controls	/	/	/	/

Note: Partial correlations controlling for CA in the control group are shown in parentheses.

* $p < .05$.

** $p < .01$.

3.3. Discussion

In this second experiment, the DS adults were proposed a new task designed to investigate their ability to attribute a facial emotional expression according to a context. The emotions of joy, sadness, anger, and fear were assessed while the neutral expression was used as a distracter. The main results showed that the DS adults only differed from their control group in the attribution of the item of sadness, for which they obtained poorer performances. Their attribution of this expression was worse than the other three, while no significant differences appeared between the expressions of joy, anger, and fear. The control group performed similarly for the various expressions, except for fear for which the attribution was poorer than that for the expression of joy. The analysis of the error pattern showed that all participants rarely selected an emotion in the opposite hedonic tone (e.g., joy for anger). However, this was not true in the DS group for the sad expression, for which the emotion of joy was preferentially substituted. Furthermore, the DS adults rarely proposed this expression throughout the task, and the error rate for sadness was smaller than for any other expressions. Finally, the correlational analyses showed few significant relations between the emotion

attribution task and cognitive competences or facial expression processing skills. We however observed that the emotion of sadness was related to the selective attention measure in both groups, as well as with the expression identification and expression matching tasks in the DS group.

4. General discussion

In this study, we investigated facial expression processing and the ability to attribute an emotion to a context in adults with DS through two experiments. In Experiment 1, the capacity to process facially expressed emotions was examined following Hippolyte et al.'s (2008) previous work. Modifications were introduced to their experimental procedure to enhance the task sensitivity by increasing the number of items and distracters. In addition, new items were presented for the neutral expression. In Experiment 2, the ability to attribute a facial emotional expression to a social context was assessed through a new task specifically created for people with ID. The relationships between results on these experimental tasks and cognitive measures were explored in order to better understand the abilities involved in emotional processing.

In Experiment 1, we first observed that the DS group accomplished the identity matching test controlling for basic face processing skills as well as the control group. Of interest, the DS participants maintained a good performance in the first two subtests (complete faces similar and dissimilar), even though the difficulty level had been increased by adding a second distracter to the Bruce et al.'s original version (2000). Both groups performed poorly on the last three subtests in which some features (ears, hair, eyes) were concealed. These results replicated Hippolyte et al.'s findings and corroborated previous research on DS children (Williams et al., 2005; Wishart et al., 2007; Wishart & Pitcairn, 2000). Furthermore, our results strengthen the hypothesis that DS individuals can successfully perform facial tasks when no emotional demand is introduced. Concerning the facial expression tasks, the DS group generally performed well on the identification task, but their results were significantly poorer than those of their controls for all expressions except sadness. These results differed from those obtained by Hippolyte et al., as the DS group performed the emotion of joy and anger as well as their controls in that study. These differences might be explained by the increased level of difficulty in the new version of the task (the addition of a second distracter), as well as by the control group's performances which were almost at the ceiling for these two emotions. In relation to the neutral expression, intra-group analyses showed that the DS participants identified it worse than all the other

expressions. Theses results strengthen the assumption that DS adults have a particular impairment to processing neutral expressions.

Similarly to Hippolyte et al.'s previous results, the expression matching task in our experiment was completed with great difficulty by the DS adults. Yet the analyses conducted separately per emotion revealed that the DS participants processed the emotion of joy better than the other expressions. The authors suggested that the DS group's failure might be due to a bad comprehension of the task instructions, but we found in our study that most of the DS participants did the trial item (emotion of joy) well. We may rather relate their poor performances to the cognitive demands of the task, for which the level of difficulty was, in our view, higher than the other two expression tasks (identification and recognition). To successfully complete it, participants first had to define the emotion of the target face and then had to recognize it in another face. Considering the DS group's significant failure in this task, it might be more interesting to propose an easier version in subsequent studies. For instance, some studies with DS children (e.g., Williams et al., 2005; Wishart et al., 2007) have successfully administered a matching task in which the emotion of the target face was orally named by the experimenter. This procedure could easily be transferred to our task.

In the facial discrimination task, the results observed in the DS group corroborated Hippolyte et al.'s main findings, with a specific difficulty to rate the neutral faces and a tendency to assess expressions as being more positive than they actually were. Interestingly, the strong relation observed by Hippolyte et al. between the neutral expression and the EVIP-R score was replicated as well. These findings sustained the assumption that there is a particular link between the ability to recognize the neutral expression and the receptive vocabulary level in DS adults. We might thus advance that the recognition of the neutral expression in this task is hindered in the DS group by difficulties to understand its conceptual representation. However, our experimental design did not allow for further investigation of this hypothesis. The meaning and the interpretation people with DS attribute to a neutral expression should be explored in subsequent research.

More generally, the correlational analyses pursued between the facial expression tasks and the cognitive competences stressed the positive impact of the receptive vocabulary in the success of these tasks in the DS group. These results contrasted with findings from previous research in DS children (Williams et al., 2005; Wishart et al., 2007), in which no correlation appeared between language ability and performance in the emotional tasks. However, these studies conducted analyses on the task global score and not separately per emotion, which might have hidden relations. In our study,

not all facial expressions were related to the receptive vocabulary measure.

Regarding the results of the emotion attribution task proposed in Experiment 2, the main findings showed that the DS adults only differed from the control group in the attribution of the sad emotion, for which they obtained poorer performances. Of interest, it was found in Experiment 1 that they generally processed this expression as well as their controls, suggesting that there is, in this group, a dissociation between the ability to process the emotion of sadness and to attribute it to a social context. The analysis of the DS adults' response pattern stressed a tendency to preferentially attribute the emotion of joy for the sad items. Such confusion was also remarked in the control group, but to a lesser extent. A part of these errors might be related to an observation we made during the assessment. We noticed that several participants did not focus their attention on the pertinent element of the drawing raising the emotion. For instance a participant might not spot the wounded bird lying on the ground in front of Marco (but rather the little flowers on the side), and considered him happy in this situation (to be seated in a meadow in flower). This hypothesis may be sustained by the significant positive correlations observed between these items and the selective attention task in both groups; participants might have particular difficulties to engage attentional resources on the negative element of the item.

In addition, we found positive relations between the score for the items of sadness and the expression matching and expression identification tasks in the DS group, showing that participants who were better at processing facial expressions obtained a higher attribution score for this emotion. We noticed that the DS adults did not only poorly perform on the items of sadness, but they also rarely attributed this expression throughout the task. This was confirmed by their error rate for sadness which was significantly lower than for any other expressions. We might thus suggest that the DS group tended to deliberately avoid the attribution of this emotion. Of interest, this tendency was specific to the sad emotion and did not apply to the other negative emotions. These results contrasted with the error pattern found by Kasari et al. (2001) and Porter et al. (2007) in DS children, as they observed that these children tended to confuse various negative emotions (anger, fear or sadness) as positive ones. Furthermore, the DS group did not show a particular strength in attributing the emotion of joy, or a tendency to more frequently propose this emotion through the task. These findings also contrasted with results found in Experiment 1, in which the DS adults showed strengths in processing this emotion as well as a tendency to assess facial expressions as being more positive than they actually were.

Another interesting result concerns the relatively good performance found in the DS group for the fear expression. These findings might be surprising considering the results

previously reported in the literature; most studies investigating this expression in DS children observed particular deficit in its recognition (Kasari et al., 2001; Williams et al., 2005; Wishart et al., 2007; Wishart & Pitcairn, 2000) and attribution (Kasari et al., 2001). Furthermore, the developmental literature shows that fear is recognized later (around 6 years) than other basic emotions (e.g., joy, sadness, or anger) (Bullock & Russell, 1986). In this experiment, we did not find any relation between the success rate for the fear expression and specific cognitive competences or emotion processing abilities. The DS adults' performances could be related to their own life experience. This emotion is frequently discussed in DS people's daily life. Caregivers and families regularly warn them about situations which might be dangerous (e.g., talking to strangers, compliance with others' demands, etc). To check this assumption, it would be interesting to examine other adult populations with ID and see if they also present a stronger attribution of this emotion. In addition, in the present study we did not control the processing of the facial emotion of fear. This emotion was not assessed in Experiment 1, which might be stressed as a limitation. It would be important to add this expression to the experimental tasks for subsequent studies, and see whether or not DS participants showed a dissociation between their abilities to process and attribute the fear expression.

Contrary to our expectations, only a few significant relations were found between the emotion attribution task and expression processing skills in both groups, suggesting an absence of direct relations between these two aspects of emotional competences. These findings might be explained by the greater complexity of the attribution task; if the ability to recognize facial emotions to be attributed constitutes a prerequisite to solve this task, it involves the ability to infer others' emotional state. Furthermore, few relations appeared between the emotion attribution task and the specific cognitive competences, thus corroborating studies in DS children which show no relation between their attribution task and mental age (Kasari et al., 2001; Wishart & Pitcairn, 2000) or verbal age (Turk & Cornish, 1998). Our task design which reduced the implication of verbal skills to a maximum, could explain the lack of correlations with the receptive vocabulary measure. Moreover, it is also possible that more complex language measures (e.g., syntactic comprehension) would show relations. The importance of language abilities in the success of tasks related to the theory of mind has been stressed in several studies conducted in populations with ID (diverse aetiologies) (e.g., Abbeduto, Short- Meyerson, Benson, & Dolish, 2004; Charman & Campbell, 2002; Thirion-Marissiaux & Nader-Grosbois, 2008).

Important variations were observed in the DS group's results according to the task modalities. These findings showed the impact that a particular emotional task might

have on the participants' performances and stressed the relevance to assess these abilities with several tasks. Despite these result variations, the different tasks proposed in this study allowed specificities in the DS adults' response pattern to be highlighted. Corroborating Hippolyte et al.'s findings, our results emphasized a general impairment in the processing of the neutral expression, as well as a tendency to overly positively judge facial expressions. The implications of this particular facial expression processing for other aspects related to the social and relational sphere would be interesting to explore in further research. In addition, the causes for the DS adults' impairment with the neutral expressions needs to be further investigated. In relation to the emotion attribution task, this new tool seemed to have the correct sensitivity to assess people with a moderate ID. Furthermore, it also allowed for a more qualitative approach through the possibility of analysing participants' response pattern. The tendency found in the DS group to avoid attribution of the sad emotion constitutes, in our view, a result of great interest, providing further information on the DS adults' emotion processing pattern. It would be important to see if further studies replicate this bias. Finally, the specificity of the DS adults' response pattern needs to be confirmed. The results of our study showed that the individuals with DS presented particularities in their response pattern in comparison to TD children. However, this study does not allow us to ascertain that this pattern is specific to DS in relation to other populations presenting a genetic disorder associated with ID. It would be important in the future to conduct comparative studies in order to investigate this issue.

References

Abbeduto, L., Short-Meyerson, K., Benson, G., & Dolish, J. (2004). Relationship between theory of mind and language ability in children and adolescents with intellectual disability. Journal of Intellectual Disability Research, 48,150-159.

Bach, L.J., Happe, F., Fleminger, S., & Powell,J. (2000). Theory of mind: Independence of executive function and the role of the frontal cortex in acquired brain injury. Cognitive Neuropsychiatry, 5,175-192.

Barisnikov, K., Van der Linden, M., & Catale, C. (2004). Tache d'attribution émotionnelle. Geneva: unpublished.

Bieberich, A. A., & Morgan, S. B. (2004). Self-regulation and affective expression during play in children with autism or Down syndrome: A short-term longitudinal study. Journal of Autism and Developmental Disorders, 34, 439-448.

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Import, A., Langton, S., McAuley, S., & Wright, R. (2000). Testing face processing skills in children. British Journal of Developmental Psychology, 18, 319-333.

Bullock, M., & Russell, J. A. (1986). Concepts of emotion in developmental psychology. In Izard,

C., & Read, P. B. (Eds.), Measuring emotions in infants and children. vol. 2 (pp.203-237). Cambridge: Cambridge University Press.

Carlson, S. M., Moses, L. J., & Hix, H. (1998). The role of inhibitory control in young children's difficulties with deception and false belief. Child Development, 69, 672-691.

Carr, J. (1995). Down's syndrome: Children growing up. Cambridge: Cambridge University Press.

Charman, T., & Campbell, A. (2002). Theory of mind and social competence in individuals with a mental handicap. Journal of Developmental and Physical Disabilities, 14, 263-275.

Coe, D. A., Matson, J. L., Russell, D. W., Keith, J. S., Capone, G. T., Baglio, C., & Stallings, S. (1999). Behavior problems of children with Down syndrome and life events. Journal of Autism and Developmental Disorders, 29,149-156.

Dunn, L., & Dunn, L. (1981). Peabody picture vocabulary test - Revised: Manual for forms L and M. Circle Pines, MN: American Guidance Service.

Dunn, L., Theriault-Whalen, C. M., & Dunn, L. M. (1993). Peabody picture vocabulary test - Revised. Toronto, ON: Psycan.

Dykens, E., Hodapp, R. M., & Evans, D. W. (1994). Profiles and development of adaptative behavior in children with Down syndrome. American Journal on Mental Retardation, 98, 580-587.

Ekman, P., & Friesen, W. V. (1976). Facial affect slides. Palo Alto, CA: Consulting Psychologists Press.

Fidler, D. J., Most, D. E., & Philofsky, A. (2008). The Down syndrome behavioural phenotype: Taking a developmental approach. Down Syndrome Research and Practice, 37-44.

Gunn, P., & Cuskelly, M. (1991). Down syndrome temperament: The stereotype at middle childhood and adolescence. International Journal of Disability, Development and Education, 38, 59-70.

Hippolyte, L., Barisnikov, K., & Van der Linden, M. (2008). Face processing and facial emotion recognition in adults with Down syndrome. American Journal on Mental Retardation, 11, 292-306.

Jahromi, L. B., Gulsrud, A., & Kasari, C. (2008). Emotional competence in children with Down syndrome: Negativity and regulation. American Journal on Mental Retardation, 113, 32-43.

Kasari, C., Freeman, S. F. N., & Hughes, M. A. (2001). Emotion recognition by children with Down syndrome. American Journal on Mental Retardation, 106, 59-72.

Kaufman, A. S., & Kaufman, N. L. (1983). Kaufman Assessment Battery for Children. Circle Pines, MN: American Guidance Service.

Korkman, M., Kirk, U., & Kemp, S. (2003). NEPSY: Bilan neuropsychologique de l'enfant-manuel. Paris: Les Editions du Centre de Psychologie Applique.

Porter, M., Coltheart, M., & Langdon, R. (2007). The neuropsychological basis of hypersociability

in Williams and Down syndrome. Neuropsychologia, 45, 2839-2849.

Raven, J. C., Court, J. H., & Raven, J. (1998). Progressive matrices—Colour. Oxford, UK: Psychologist Press.

Rojahn, J., Rabold, D. E., & Schneider, F. (1995). Emotion specificity in mental retardation. American Journal on Mental Retardation, 99, 477-486.

Thirion-Marissiaux, A.-F., & Nader-Grosbois, N. (2008). Theory of Mind ‘‘emotion’’, developmental characteristics and social understanding in children and adolescents with intellectual disabilities. Research in Developmental Disabilities, 29, 414-430. Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). The Stanford Binet Intelligence Scale. Chicago: Riverside.

Turk, J., & Cornish, K. (1998). Face recognition and emotion perception in boys with fragile-X syndrome. Journal of Intellectual Disability Research, 42, 490-499.

Williams, K. R., Wishart, J. G., Pitcairn, T. K., & Willis, D. S. (2005). Emotion recognition by children with Down syndrome: Investigation of specific impairments and error patterns. American Journal on Mental Retardation, 110, 378-392.

Wishart, J. G., Cebula, K. R., Willis, D. S., & Pitcairn, T. K. (2007). Understanding of facial expressions of emotion by children with intellectual disabilities of differing aetiology. Journal of Intellectual Disability Research, 51, 552-563.

Wishart, J. G., & Pitcairn, T. K. (2000). Recognition of identity and expression in faces by children with Down syndrome. American Journal on Mental Retardation, 105, 466-479.

We are grateful to Johannes Rojahn and his colleagues for their permission to use the facial discrimination task, which was supported by the John D. and Catherine T. MacArthur Foundation. This research was supported by the Swiss National Science Foundation (SNSF) (grant number 100014120657/1).