AMERICAN JOURNAL ON INTELLECTUAL AND DEVELOPMENTAL DISABILITIES
2012, Vol. 117, No. 5, 368–383

DOI: 10.1352/1944-7558-117.5.368

Candidate Socioemotional Remediation Program for Individuals with Intellectual Disability

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Abstract

The authors developed a computerized program, Vis-à-Vis (VAV), to improve socioemotional functioning and working memory in children with developmental disabilities. The authors subsequently tested whether participants showed signs of improving the targeted skills. VAV is composed of three modules: Focus on the Eyes, Emotion Recognition and Understanding, and Working Memory. Ten children with idiopathic developmental delay completed four 20-min weekly sessions of VAV for 12 weeks with an adult. Participants were evaluated before (Time 0) and after (Time 1) training and 6 months after remediation (Time 2). Subjects improved on all three modules during training and on emotion recognition and nonverbal reasoning post-VAV. These gains were still present at Time 2. VAV is a promising new tool for working on socioemotional impairments in hard-to-treat pediatric populations.

Key Words: *cognitive remediation; face processing; emotion recognition; Vis-à-Vis*

1. Introduction

One of the essential roles of face recognition is to understand and identify others' emotions, thus serving a vital role in our day-to-day functioning and survival. Much facial emotional information is conveyed through the eyes, and from the beginning of postnatal life, babies are hardwired to largely focus on the eyes of a face (see Senju & Johnson, 2009, for a review). However, despite such early tendencies, or perhaps due to its complexity, face recognition is acquired slowly and does not reach adult levels until adolescence (Taylor, Batty, & Itier, 2004).

Protracted development of face-processing skills (Mondloch, Le Grand, & Maurer, 2002; Taylor et al., 2004) increases susceptibility to impairment in individuals with atypical development (van Rijn et al., 2010). This is corroborated by evidence of perceptual and social deficits associated with impaired face processing in a variety of developmental disorders, including autism spectrum disorder, Williams syndrome, and 22q11.2 deletion syndrome (Annaz, Karmiloff-Smith, Johnson, & Thomas, 2009; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Behrmann et al., 2006; Deruelle, Rondan, Gepner, & Tardif, 2004; Glaser et al., 2010; Karmiloff-Smith et al., 2004; Lacroix, Guidetti, Roge, & Reilly, 2009; Wolf et al., 2008). Atypical scanning or exploration of faces, as measured by eye tracking, also is observed in various neurodevelopmental disorders (Campbell et al., 2010; Glaser et al., 2010; Hernandez et al., 2009; Mazzola et al., 2006), with affected individuals showing reduced exploration of the eye area and spending significantly less time looking at people's eyes. Accordingly, children with developmental disabilities often demonstrate deficits in their ability to recognize facial expressions (Bloom & Heath, 2010; McAlpine, Kendall, & Singh, 1991; Zaja & Rojahn, 2008). However, though similar cognitive impairments affecting socioemotional abilities, such as a deficit of holistic face-processing skills (Annaz et al., 2009), often result from different neurodevelopmental pathologies, it still stands to reason

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that individuals may benefit from similar educational solutions targeting these core impairments.

Remediation enhances cognitive function by engaging and training underutilized brain systems through repeated practice (Wykes et al., 2002). Training programs have been developed to improve recognition of facial expressions (Penn & Combs, 2000) and tested in children and adults with schizophrenia or autism (Baron-Cohen et al., 2001; Bolte et al., 2002; Frommann, Streit, & Wolwer, 2003; Gil Sanz et al., 2009; Golan et al., 2010; Grinspan, Hemphill, & Nowicki, 2003; Russell, Green, Simpson, & Coltheart, 2008; Silver, Goodman, Knoll, & Isakov, 2004; Silver & Oakes, 2001; Stewart & Singh, 1995; Tanaka et al., 2010; Wolwer et al., 2005). These training programs have durations ranging from two to 12 weeks and appear to significantly improve face recognition. Half of these programs also teach contextualization of emotions using short stories (Frommann et al., 2003; Golan et al., 2010; Silver & Oakes, 2001; Stewart & Singh, 1995; Tanaka et al., 2010).

However, the current training programs have a number of limitations: First, in many previous studies of cognitive retraining, both the evaluations and the training have been based on repetitions of the same exercise (Faja, Aylward, Bernier, & Dawson, 2008), compromising both generalizability and interest in the study results. Second, despite the importance of focusing on the eyes to emotion recognition, only two previous programs have incorporated "eye" exercises (Hopkins et al., 2011; Tanaka et al., 2010). Third, to our knowledge, long-term maintenance of remediation effects has not been investigated in previous studies. Finally, apart from one program in German (Bolte et al., 2002), most programs originated commercially and are available only in English, leaving non-English speakers with fewer opportunities for research-based interventions.

The aim of our study was to develop and pilot a computerized training program in French for research purposes (free of the conflicts of interest that are inherent to developing a program for commercial use) to teach skills that have been shown to significantly improve emotion recognition and reasoning skills. Our goal was to pilot the program with an appropriate subject group to evaluate whether the games were appropriate for the age and cognitive level of the participants and whether the participants showed signs of improving the targeted skills. We chose to target three key cognitive areas—focusing on the eyes of a face, emotion recognition and understanding, and nonverbal working memory—for the following reasons: First, research on children with neurodevelopmental conditions causing mental retardation demonstrates that participants spend less time on the eye area of the face, affecting both facial recognition (Glaser et al., 2010) and emotion recognition (Campbell et al., 2010), and suggests that learning to spend time on the eyes may be key to recognizing emotions. Second, it has been proposed that learning the universal physiognomy of facial expressions of emotions (Ekman & Friesen, 1971), as well as being given examples of the mental states underlying the expressions (Golan, Baron-Cohen, & Golan, 2008), may help children with socioemotional impairments to better recognize and respond appropriately to emotions. Third, visuospatial working memory has been shown to improve nonverbal reasoning skills and attention (Klingberg et al., 2005), which in turn help children to process emotional cues and pay better attention in social situations. In addition, the prefrontal cortical regions underlying working memory (Goldman-Rakic, 1996) are some of the last to reach maturity (Gogtay et al., 2004), and consequently, prefrontal cognitive functions may be especially vulnerable in children with abnormal brain development networks.

We used the following criteria to evaluate the success of the program in individuals with idiopathic developmental disabilities: first, progress was measured by changes between the preremediation evaluation (Time 0) and two postremediation cognitive evaluations immediately after remediation (Time 1) and 6 months after the end of remediation (Time 2; Figure 1). Second, the skills learned during remediation were tested to see whether they could be generalized to correspond to improvement on evaluation measures that are different from the remediation exercises. Third, a short evaluation was given 6 months after the end of remediation to evaluate the maintenance of participants' progress.

2. Material and Methods

2.1. Participants

Ten children with idiopathic developmental delay (three girls, seven boys) aged between 7 and 10 years old (M age = 8 years ± 9 months) were recruited from a therapeutic elementary school

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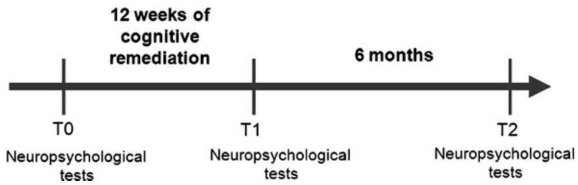

Figure 1. Design of the study. The remediation period lasted 12 weeks. Three cognitive evaluations were performed at different time points.

(Table 1). One child was excluded from our statistical analyses because he left school before the third evaluation (three girls, six boys; *M* age = 8 years, 4 months). Participants were evaluated onsite at their school facilities. A detailed medical history was first reviewed for each child to exclude individuals with known genetic disorders, as well as malformations and birth defects. Study participants needed to understand the words *happy*, *sad*, *surprised*, *angry*, *disgusted*, and *afraid* and be able to explain each word to a psychologist, Mélanie Chabloz. All of the children were fluent and had always been schooled in French. All testing and program sessions were administered in French. None of the children was receiving treatment for psychiatric concerns, except for one child who had been diagnosed with attention deficit/hyperactivity disorder and was receiving methylphenidate treatment (20 mg/day). His medication dose did not change during the study period. Participants' parents gave written informed consent to the study protocol approved by the university's institutional review board.

2.2. Program Design

Vis-à-Vis (VAV) was created in French and consists of four 20-min computerized sessions per week for 12 weeks. Chabloz worked individually with each participant during the sessions, which were completed on Mondays, Tuesdays, Thursdays, and Fridays during morning school hours. The program was designed to last 12 weeks because previous studies had been shown effective after approximately 12 weeks or less (Golan & Baron-Cohen, 2006; Wykes et al., 2002). It is known that children with learning disabilities especially enjoy working with computers (Chen & Bernard-Opitz, 1993; Huttinger, 1996), and the interface was designed for both ease (operated by a mouse) and enjoyment. VAV was created and administered using E-Prime software (Version 2, http://www.pstnet.com).

2.3. General Information About the Program

VAV is composed of three "modules" or main cognitive domains: Focus on the Eyes, Emotion Recognition and Understanding, and Working Memory. Each module consists of different exercises (nine total), each of which is practiced twice per week over the course of the remediation period (see Table 2 for program structure). A short teaching module precedes two of the weekly sessions and gives concrete examples of the emotions by explaining specific anatomical features associated with each emotion, giving an example of that emotion using a vignette or by showing an animated cartoon sequence (*Tom and Jerry*) in which a character demonstrates said emotion. Each teaching module uses unique examples and covers the emotions presented in the exercises that week.

Because each of the nine exercises and a teaching module are done twice per week, the four weekly practice sessions contain five components: either both a teaching module and four of the exercises or five of the exercises. The exercises are individually randomized within the first two (one and two) and the last two (three and four) of the four weekly practice sessions to ensure that each session is completed in a different order for each participant and so that the first and second sessions of each exercise fall at the beginning and end, respectively, of the participant's remediation week. The teaching modules always precede the sessions with four exercises. Each session is different from all of the other iterations of that exercise, and the exercises become progressively more difficult throughout the 12 weeks (see 2.4 for details). For all the exercises, participants choose their answers using the mouse, the input device that is easiest for young individuals to manipulate. VAV is based on the principles of errorless learning, a technique that teaches children to discriminate between two stimuli before asking them to employ their learning. Errorless learning is based on direct positive reinforcement for correct answers and the repetition and recall of newly learned material. It has been shown to be especially effective when used with individuals with amnesia and mental retardation (Baddeley & Wilson, 1994; Sidman & Stoddard, 1967).

VAV was developed for children ages 7–16 years, the developmental period during which face and emotion processing progress to adult

Table 1
Clinical Data

Subject	Gender	Age	Full-Scale IQ ($M = 100 \pm 15$)	Verbal IQ ($M = 100 \pm 15$)	Nonverbal IQ ($M = 100 \pm 15$)	Index of Attention/ Concentration from the Children's Memory Scale ($M = 100 \pm 15$)	Revised Children's Manifest Anxiety Scale ($M = 50 \pm 10$)	Children's Depression Inventory ($M = 50 \pm 10$)
1	Girl	8 y, 1 m	89	86	88	96	48	46
2	Boy	8 y, 5 m	72	76	82	99	58	50
3	Girl	7 y, 9 m	63	84	71	75	44	58
4	Girl	8 y, 8 m	67	57	79	135	55	65
5	Boy	7 y, 6 m	74	96	79	81	28	39
6	Boy	10 y	73	69	96	113	49	45
7	Boy	8 y, 10 m	72	101	69	87	24	37
8	Boy	8 y, 2 m	76	69	92	93	70	44
9	Boy	7 y, 5 m	83	86	92	75	61	67
10	Boy	8 y, 4 m	62	61	69	71	38	49
M (SD)		8 y, 4 m (9 m)	73.1 (8.33)	78.5 (14.57)	81.7 (10.04)	92.5 (19.77)	47.5 (14.50)	50 (10.25)

Note. y = year, m = month.

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DOI: 10.1352/1944-7558-117.5.368

Table 2
Structure of the Vis-à-Vis Program

Module	Exercises			
I. Focus on the Eyes	1. Puzzle	2. Eye–Emotion Matching	3. Eye–Face Matching	4. Multiple Choice
II. Emotion Recognition and Understanding	1. Stories	2. Context		
III. Working Memory	1. Simon	2. Sheep	3. Memory	

levels (Mondloch et al., 2002). In the emotion exercises, we chose to teach and train the neutral emotion calm, along with six of the universal facial expressions (happiness, sadness, anger, fear, disgust, surprise) described by Paul Ekman (Ekman & Friesen, 1971) and their associated mental states. In the two emotion modules (Focus on the Eyes; Emotion Recognition and Understanding), participants worked on two to seven emotions at the same time, depending on the difficulty level that week. Each round was composed of two items testing each emotion. The emotions were associated with specific color labels (which remained consistent across exercises and during the entire 12 weeks) to help children who could not read fluently (our younger participants) and to promote learning about the emotions by associating each affect to a color (red for anger, yellow for happiness, etc.). Remediation sessions were always done with a trained psychologist to encourage dialogue about the games and provide clarification, if necessary, and external motivation for when the difficulty level increased. Participants were able to discuss the stories and expressions with their adult mentor, which reinforced their interest and learning and put learning about human emotion in a social context.

To facilitate the generalization of the skills being taught and to make the games as realistic as possible, we created a database of 1,000 photographs of women and men from different origins demonstrating seven universal facial expressions (happiness, sadness, anger, fear, disgust, surprise, neutral). The pictures were digitalized and normalized for size (size = 328 × 428 pixels). A group of 10 adults (age range = 22–33 years, sex ratio = 4 men to 6 women) were tested on the emotion expressed in each photograph. We then compiled the photographs for which our testers showed at least 90% agreement. A selection of these correctly identified photographs (approximately 500) was used to create the face- and emotion-recognition exercises. During the face-recognition exercises, feedback was immediately provided after both correct and incorrect answers to explain the critical features of the emotion expressed in the item.

2.4. Program Content

The Focus on the Eyes module was composed of four exercises: Puzzle, Eye–Emotion Matching, Eye–Face Matching, and Multiple Choice. In the Puzzle exercise, facial photographs were hidden by four pieces: Two pieces hid the upper portion of the face (the eye area), and two pieces hid the lower half of the face (the mouth area). Participants were asked to identify the hidden facial expression by first clicking on the pieces to uncover the face. A point counter next to each face rewarded participants with two points for identifying the expression only from the eye area, one point for identifying the expression using all four pieces or from one piece of the eye area and one piece of the mouth, and minus one point for identifying the expression only from the two pieces covering the mouth area. The point system was added to the game to keep children motivated (they tried to reach maximum points, or the top of the point bar, by the end of each round of the exercise) and to discourage them from focusing on the mouth area of the face when they were identifying emotions. Eye–Emotion Matching was divided into three parts. In the first part, only the eye area of the face was visible, and the children had to identify the correct emotion by reading the eyes. They then confirmed their choice when presented with the entire face. In the second part of the exercise, children were given the emotion and asked to choose the pair of eyes that was the best match. The last part was an ultrarapid presentation of a face (250 ms), and participants were given prior instructions to look mainly at the eye area while the face was presented and try to identify the facial expression. The idea that ultrarapid face presentation may help participants to focus on the eyes comes from work using low-grade spatial frequency photos (Vuilleumier,

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Armony, Driver, & Dolan, 2003). In the Eye–Face Matching exercise, faces without the eye area were shown, and participants chose the eyes that best matched the faces and facial expressions. The different emotion choices always derived from the same facial identity. Given poor eye exploration in children with neurodevelopmental disorders (Glaser et al., 2010; Klin, Jones, Schultz, Volkmar, & Cohen, 2002), this module encouraged participants to concentrate on the eye area to match the faces. In the Multiple Choice exercise, complete photographs of faces were presented centrally on a black background. Children looked at a single photograph representing an emotion and were asked to choose the correct emotional label by clicking on the name of the emotion. It should be noted that although the Multiple Choice exercise was designed to be part of the Emotion Recognition and Understanding module, in the current study, we have included it with the Focus on the Eye module due to the fact that its interface (emotion matching) is more similar to the faces games, and participants probably concurrently improved their performance on games that are structured in similar ways.

The Emotion Recognition and Understanding module was composed of two exercises aimed at teaching participants to understand the six universal emotions: Stories and Context. Emotion recognition is one of the keys to being able to interact with other individuals and to being able to label emotion in oneself and in others, which is thought to help reduce anxiety (Lieberman et al., 2007). In this module, we aimed to teach participants to label emotions, understand how one person's emotional state can change through experience, and how different people have different emotional reactions to the same experience. Furthermore, the texts and stories in these two exercises were designed to expand participants' emotional vocabularies to better equip them to label their feelings.

In the Stories exercise, children followed the "adventure" of one character, whose feelings change according to his or her experiences during a multi-episode story. This teaches emotional flexibility, as well as an emotional vocabulary. Participants were asked to choose the emotion felt by the character at each critical juncture in the story and find the photograph corresponding to that emotion (from among a choice of photographs representing two to six emotions, without neutral).

The Context exercise consisted of a short story illustrated by a contextual photograph from a scene (without a human face). Children then chose the facial expressions associated with the emotions in the story. In this exercise, several different characters appeared. Reactions from 12 native French-speaking adults (age range = 22–60 years, sex ratio = 5 men to 7 women) were used to validate the emotions encountered in the different stories. This module taught the idea that situation, as well as events changing mental state, can trigger different emotional responses. It is also based on the Theory of Mind, the ability to attribute a mental state to oneself or another person (Premack & Woodruff, 1978). It allowed participants to access a broader understanding of emotions, beyond identifying the seven universal emotions, and helped them to develop a vocabulary related to emotions. Increases in difficulty in both emotion modules were due to an increase in the number of emotions that were compared (two to seven emotions and situations that are increasingly complex).

Given that executive functions have been successfully remediated in studies with patients with different psychiatric disorders (Sartory, Zorn, Groetzinger, & Windgassen, 2005; Wasserstein & Lynn, 2001; Wykes et al., 2002), the Working Memory module had a double function: as a control module to test the effectiveness of the program and as an incentive for participation for individuals needing to improve their attention and reasoning skills, in the absence of specific socioemotional impairments. Working memory affects a wide variety of academic skills (Monette, Bigras, & Guay, 2011), such as reading, mathematics, and spelling, and is often one of the cognitive constructs affected in persons with mental retardation (Pennington & Ozonoff, 1996). The Working Memory module was composed of three visuospatial working memory exercises: Simon, Sheep, and Memory. In Simon, a spatial span exercise, a series of lights (from three to six) went on and off one by one in a visuospatial grid (ranging in size from 3-by-3 [9] to 4-by-4 [16] lights). Participants were then asked to reproduce the sequence in order. The Sheep exercise also was based on the spatial span principle: a group of animals (6 to 10 in total) displayed in randomized scattered group formations on the screen disappeared one at a time (in sequences of 3 to 6 animals) and either stayed disappeared (easier version) or came back.

Children then reproduced the disappearing sequence by clicking the mouse in order of their disappearance. Finally, the Memory exercise was composed of sets of cards that were facedown (from 8 to 36 cards in total). Children searched for identical pairs of cards and were encouraged to look at the cards in order and try and remember the placement of the cards to minimize their searching. A counter was used to motivate participants to beat the score of the day. Difficulty was increased through the amount of mnemonic information (three-item sequences to six-item sequences in the Sheep and Simon exercises and grids that increased in size).

2.5. Cognitive Evaluation

At Time 0 a comprehensive cognitive evaluation was conducted (before the 12 weeks of remediation; Figure 1), including a full Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2005) with the optional subtest Arithmetic, along with the two subtests (Sequences and Picture Location) from the Children's Memory Scale (CMS; Cohen, 1997/2001) needed to calculate the Attention/Concentration composite score. The WISC-IV was done only at Time 0 to give us a baseline for the cognitive level of the child, whereas the working memory and attention subtests from the WISC-IV and CMS were used at each evaluation to estimate changes in working memory and attention. The Benton Face Recognition Test Long Form (BFRT; scores 0 to 54) and Raven's Colored Progressive Matrices (CPM; scores 0 to 36) for children were also administered. The BFRT assesses ability to compare photographs of faces (Benton, Sivan, Hamsher, Varney, & Spreen, 1994) and served as a standardized measure for facial identity recognition, given that focusing on the eyes may impact a child's ability to discriminate between faces. We used the CPM (Raven, 1998) to evaluate nonverbal reasoning. In this test, children were asked to identify the missing item that completed the pattern. Training of working memory has been shown to improve performance on the CPM in previous studies (Klingberg et al., 2005), therefore, using the CPM also helped us to monitor whether our remediation program was effective compared with previous interventions. All children completed the Revised Children's Manifest Anxiety Scales (R-CMAS; Reynolds & Bert, 1985) and the Children's Depression Inventory (CDI; Kovacs, 1982) with the examiner during the evaluation to evaluate a potential impact of socioemotional remediation on self-rated anxiety and depression. In addition, a demographic questionnaire and a medical history form were sent to each child's parents. Emotion recognition was evaluated using a computerized multiple-choice exercise with neutral faces and four universal emotions (happiness, fear, anger, and sadness) that were taken from a standardized set of photos (Ekman & Friesen, 1976).

At Time 1 (right after the 12 weeks of the remediation program; Figure 1), a brief cognitive evaluation identical to the evaluation at Time 0 was conducted, including only the working memory subtests from the WISC-IV (a full WISC-IV was only done at Time 0), Digit Span, Letter–Number Sequence, Arithmetic; Sequences and Picture Location from the CMS; the BFRT; the CPM; the R-CMAS; the CDI; and the computerized emotion-recognition task. At Time 2 (6 months after the remediation program), only the BFRT, the CPM, and a computerized version of the multiple-choice emotion-recognition task were administered to 9 of the 10 participants due to very limited time with the subjects. We were not able to repeat testing with one of the subjects at Time 2 because he had changed schools.

2.6. Data Analysis

We first explored potential differences among neuropsychological scores from the three cognitive evaluation time points using nonparametric Wilcoxon tests (Statistical Program for the Social Sciences [SPSS], version 17.0). The significance threshold was set at $p < .05$.

We analyzed each of the three general modules of VAV (Focus on the Eyes, Emotion Recognition and Understanding, and Working Memory) from the 12 weeks of remediation separately. Results from the easiest level of each exercise were excluded from the analyses because of a ceiling effect. Participants scored almost perfectly at the easiest level because they were given a choice of only two possible answers per question to ensure that they understood the exercises.

We first weighted the remaining raw total correct scores from each subject by level of difficulty to use as dependent variables. Indeed, each exercise progressed in difficulty over the course of the remediation. For the modules Focus on the Eyes and Emotion Recognition and

Understanding, scores were weighted based on the number of emotions given as possible answers. For the module Working Memory, scores were weighted depending on the number of presented items. For the Memory exercise, the number of clicks per card (nonweighted) was used as the dependent variable.

Second, we analyzed the effectiveness of VAV based on the weighted scores. We performed univariate analyses of variance and linear regressions between total weighted correct scores (dependent variable) and exercise session number (session number goes chronologically from 1 to 24 because each exercise was given twice per week) using SPSS 17.0 for a personal computer. To evaluate progress on each emotion, we weighted the scores for each emotion and repeated the analyses on those weighted scores.

3. Results

3.1. Population

The individual IQ scores of the 10 initial participants showed mild to more severe mental retardation, between 62 and 89 ($M \pm SD = 73.1 \pm 8.3$). Participants' scores on the Attention/Concentration index (from the CMS) ranged from 71 to 135 ($M \pm SD = 92.5 \pm 19.77$). CDI scores ranged from 37 to 67 (median = 47), with two children reporting a score ≥ 65 (Table 1). The R-CMAS scores ranged from 24 to 70 (median = 48).

3.2. Cognitive Evaluation

Prior to remediation (Time 0), the mean CPM score was 24.7 ($SD = 4.9$), and the mean BFRT score was 37.3 ($SD = 3.6$; see Table 3). We observed a significant increase of CPM scores at Time 1 ($p = .046$) as well as at Time 2 ($p = .017$) compared with Time 0. But no difference was observed between scores at Time 1 and at Time 2 ($p = .734$). Similarly, we observed a significant improvement of BFRT scores at Time 2 compared with Time 0 ($p = .017$) and a nonsignificant trend at Time 2 compared with Time 0 ($p = .068$). By contrast, no difference was found between the group's BFRT scores at Time 1 and at Time 2 ($p = .932$).

Similar results were found for the emotion-recognition task. A significant increase of total correct scores on the emotion-recognition task was observed between Time 0 and Time 1 ($p = .01$) and between Time 0 and Time 2 ($p = .014$), whereas no differences were observed between Time 1 and Time 2 ($p = .14$).

3.3. Remediation Exercises

For the module Focus on the Eyes, there was an improvement in performance during remediation. The weighted scores ($M \pm SD = 0.609 \pm 0.002$) ranged from 0.136 ± 0.16 at the earliest weighted session to 0.883 ± 0.008 at the last session of remediation (session number 24). We found a significant effect of the variables Session Number ($p < .001$, $\eta p^2 = 0.968$) and Emotion ($p < .001$, $\eta p^2 = 0.560$), as well as an interaction of Emotion × Session Number ($p < .001$, $\eta p^2 = 0.268$) on the total weighted correct scores. A positive correlation between weighted correct scores and session number signals an improvement in scores during the 12 weeks, or successful remediation.

In addition, we observed a significant difference in emotion recognition ($p \leq .039$), except for the differentiation of fear and disgust ($p = .101$; Table 4). We found a significant positive correlation between session number and the total weighted correct scores ($R^2 = .511$, $p < .001$), as well as the weighted correct scores for each emotion: happiness: $R^2 = .721$, $p < .001$; sadness: $R^2 = .595$, $p < .001$; surprise: $R^2 = .565$, $p < .001$; anger: $R^2 = .29$, $p < .001$; disgust: $R^2 = .31$, $p < .001$; fear: $R^2 = .085$, $p < .001$; neutral: $R^2 = .491$, $p < .001$ (Figure 2).

For the module Emotion Recognition and Understanding, the total weighted correct scores ($M \pm SD = 0.611 \pm 0.003$) ranged from 0.347 ± 0.17 at the first considered session to 0.869 ± 0.012 at the last session of remediation. There was a significant effect of Session Number ($p < .001$, $\eta p^2 = 0.939$) and Emotion ($p < .001$, $\eta p^2 = 0.629$), as well as Session Number × Emotion interaction ($p < .001$, $\eta p^2 = 0.457$) on the total weighted correct scores. Moreover, we observed a significant difference in recognition of most emotions ($p \leq .044$), except for discrimination of surprise and three other emotions (happiness, sadness, and disgust; $p \geq .161$), and disgust and sadness ($p = .937$). Similarly, discrimination of anger and two other emotions (happiness and fear) was not significant ($p \geq .165$).

A significant positive correlation was observed between session number and total weighted correct scores ($R^2 = .361$, $p < .001$) and the weighted correct scores of five emotions:

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Table 3
Mean ± Standard Deviation Cognitive Evaluation Results at the Three Time Points

Test	Time 0 (prior to remediation)	Time 1 (after 3 months of remediation)	Time 2 (6 months after remediation)
Raven's Colored Progressive Matrices	24.7 ± 4.9	27.4 ± 6.2	27.9 ± 4.9
Benton Face Recognition Test Long Form	37.3 ± 3.6	39 ± 4.1	39.2 ± 3.6
Emotion-recognition task	63.8 ± 10	77.4 ± 6.4	70.1 ± 7.1

Table 4
Weighted Correct Scores for Each Emotion for the General Modules Focus on the Eyes and Emotion Recognition and Understanding

	Mean of weighted correct scores	
Emotion	Focus on the Eyes	Emotion Recognition and Understanding
Neutral	0.533 ± 0.005	Not tested
Happiness	0.622 ± 0.005	0.629 ± 0.008
Surprise	0.667 ± 0.007	0.612 ± 0.01
Sadness	0.551 ± 0.005	0.602 ± 0.008
Anger	0.638 ± 0.006	0.646 ± 0.009
Disgust	0.711 ± 0.008	0.601 ± 0.011
Fear	0.732 ± 0.01	0.661 ± 0.012

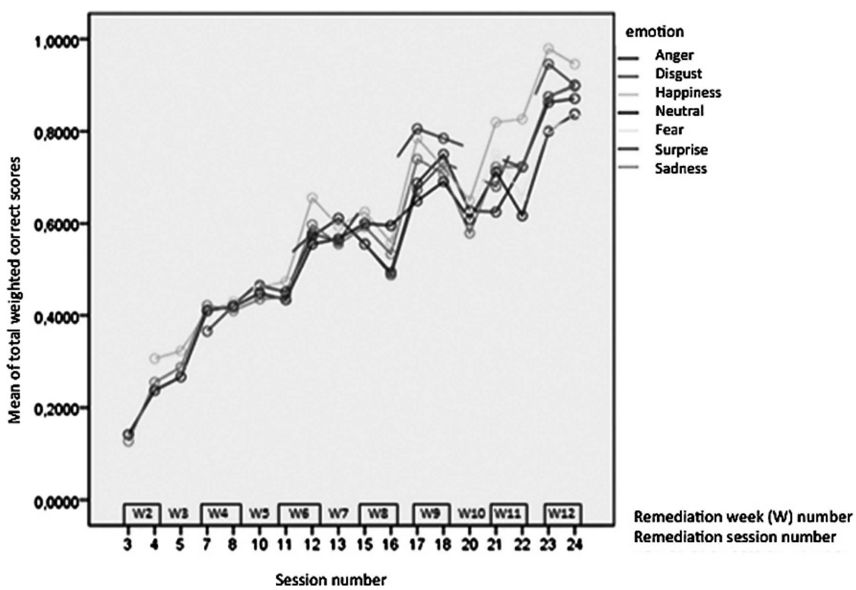

Figure 2. Graph of total weighted correct scores depending on the session number for the general module Focus on the Eyes.

happiness: R^2 = .683, $p < .001$; sadness: R^2 = .47, $p < .001$; surprise: R^2 = .448, $p < .001$; anger: R^2 = .353, $p < .001$; fear: R^2 = .451, $p < .001$ (Figure 3). Only the weighted correct scores of disgust were not correlated with session number (p = .469). As illustrated by Figure 3, it should be noted that the weighted correct scores from sessions 10, 14, and 19 correspond to a choice between only negative emotions.

For the Working Memory module, the weighted correct scores of the Sheep exercise ($M \pm SD$ = 1.785 ± 0.032) ranged from 0.427 ± 0.21 at the first session to 3.4 ± 0.121 at the last session. The weighted correct scores of the Simon exercise ($M \pm SD$ = 2.152 ± 0.033) ranged from 1.211 ± 0.246 at the first session to 3.35 ± 0.127 at the last session. For these two exercises we found a significant effect of session number on the total weighted correct scores: Sheep: $p < .001$, $\eta p^2 = 0.867$; Simon: $p < .001$, $\eta p^2 = 0.867$. We also observed a positive correlation between total weighted correct scores and session number: Sheep: R^2 = .576, $p < .001$; Simon: R^2 = .377, $p < .001$ (Figure 4).

Participants' results on the Memory exercise were inconclusive. The weighted number of clicks per card ($M \pm SD$ = 1.654 ± 0.735) ranged from 0.2 ± 0.026 at the first session to 2.48 ± 0.692 at the last session. Despite the weighting of the number of clicks per card, we did not observe a decrease in the number of weighted clicks per card throughout the remediation period as expected.

4. Discussion

In response to the lack of psychoeducational material available for children with perceptual and social deficits associated with impaired face processing, we present an innovative computerized program for teaching recognition of facial expressions and visuospatial working memory to children with developmental disabilities. This program is unique in that it was created for research (noncommercially) in French. In addition to gains in emotion recognition at the postremediation evaluations, participants showed improvement in nonverbal reasoning after 12 weeks of using the VAV remediation program. These cognitive gains were still present 6 months after the end of the remediation period.

VAV was constructed using direct positive reinforcement through feedback and frequent repetition of newly learned material. As reported in a study of teaching sight words to students, immediate feedback is more effective than delayed feedback when used with individuals with intellectual disability (Worsdell et al., 2005). In addition, given that keeping participants motivated is an essential element for a successful remediation program requiring frequent training

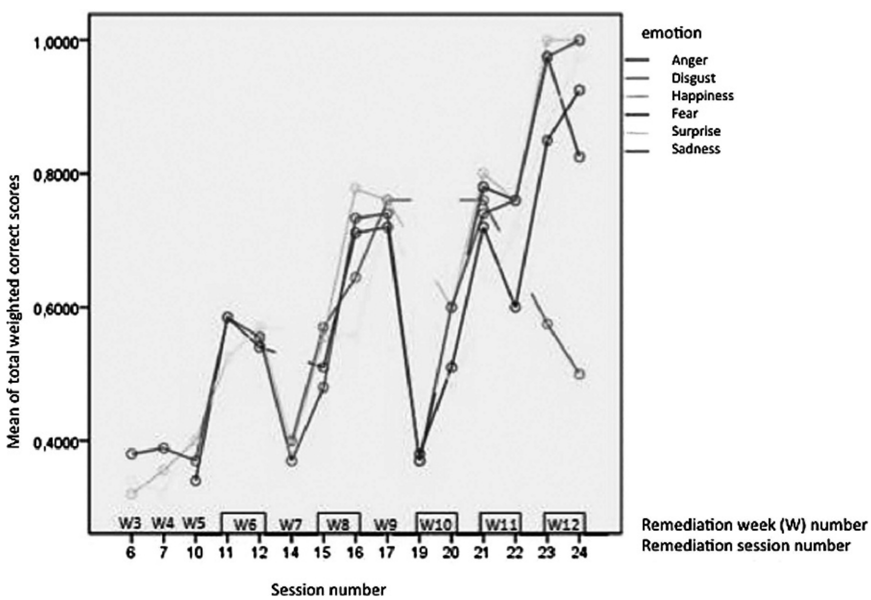

Figure 3. Graph of total weighted correct scores depending on the session number for the general module Emotion Recognition and Understanding.

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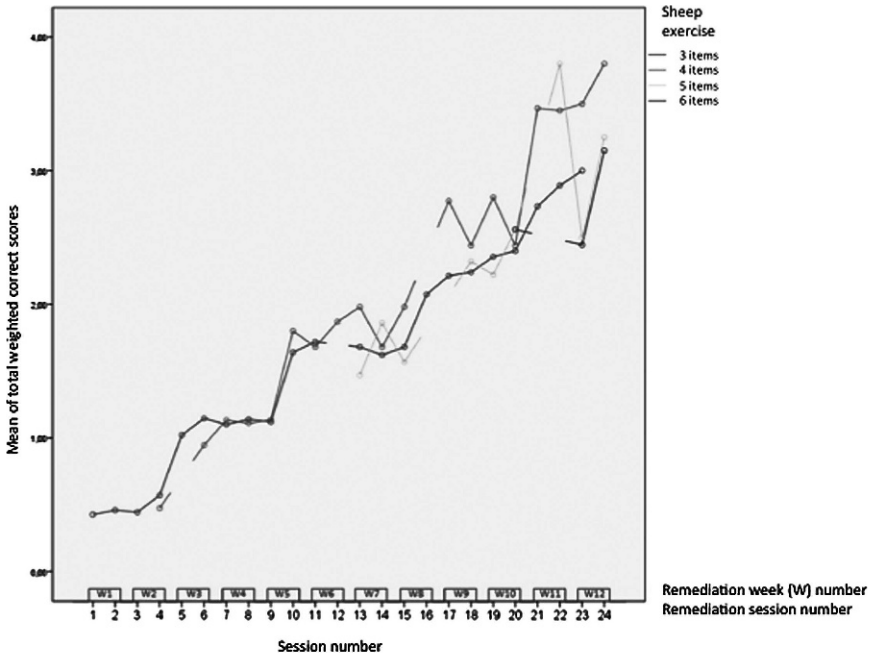

Figure 4. Graph of total weighted correct scores depending on the session number for the Sheep exercise of the general module Working Memory.

(Medalia & Choi, 2009; Schunk & Zimmerman, 2007), and one that may have been missing in previous remediation regimes, all of the VAV exercises have gamelike structures (colorful interface, interactive noises, funny graphics, motivators). The fact that VAV is done in tandem with an adult was an additional and important source of motivation to our participants, ensuring that they benefited from the adult's undivided attention and learned socioemotional material in a social context.

Our socioemotional program teaches participants to focus on the eye area to improve emotion recognition. The ability to recognize facial emotional expressions appears to be the product of an interaction between two key factors: (a) the parts of the face and (b) situational aspects (Fox, 2004). To incorporate the first factor, the VAV teaching modules presented twice weekly taught emotional facial physiognomy by dividing the facial features into three sections: eyebrows (upper), eyes (middle), and nose and mouth (lower; Fox, 2004). Further, the exercises included in the Focus on the Eyes module targeted the region around the eyes and eyebrows in particular. A recent article suggests that eye contact, or perceived direct gaze, modulates cognitive processing and behavioral responses to emotion, a phenomenon coined the "eye contact effect" by the authors (Senju & Johnson, 2009). This effect appears to sharpen a person's ability to perceive emotion. A case study of a patient with amygdalar damage illustrates this phenomenon by demonstrating that when she fixated on the eyes during an emotion-recognition task, her abilities increased to a normal level (Adolphs et al., 2005). If atypical visual scanning of faces, a frequent finding in individuals with neurodevelopmental disorders (Glaser et al., 2010; Hernandez et al., 2009; Mazzola et al., 2006), underlies impaired emotion recognition, then educational interventions need to include tasks that redirect attention to the eyes. Moreover, the significant impact of VAV on BFRT scores at Time 2 in the present study may indicate improved facial recognition, though future studies of VAV using eye-tracking technology will need to confirm this connection.

"Situational aspects," a second factor that is key to facial emotion recognition, were incorporated in VAV during the module Emotion Recognition and Understanding. The Context and Stories exercises were based on social stories (Gray, 1995, 2000) and the matching of a character's experience and his or her resulting emotion, with the goal of teaching children to generalize emotion-recognition skills to real-life situations. Previous studies have reported fewer inappropriate social behaviors in home and school settings following the use of social stories in children with autism (Kuoch & Mirenda, 2003; Smith, 2001; Swaggart, Gagnon, & Bock, 1995). Although we were not able to test the impact of the remediation on problem behaviors in the current group, we can assume that working on characters' mental states supported the observed improvements in emotion recognition (Baron-Cohen et al., 2001). In addition, exercises with texts provided key opportunities for our participants to build emotional vocabularies, learn words associated with the universal emotions (such as *disappointed*), and improve their reading skills.

We also observed a significant impact of VAV on Raven's matrices nonverbal reasoning scores at Time 1 and Time 2. This suggests that the benefits of remediation may generalize to other, nonpracticed, measures of nonverbal reasoning (Olesen, Westerberg, & Klingberg, 2004), response inhibition, complex reasoning (Klingberg, Forssberg, & Westerberg, 2002b), and fluid intelligence (Klingberg et al., 2005), as shown in previous remediation studies. Participants had maintained this improvement in nonverbal reasoning 6 months after remediation. While this maintenance effect needs to be replicated using a comparable control group, it suggests that 12 weeks of training may be sufficient to induce longer-lasting cognitive effects.

In addition to improvement at the evaluation time points, we observed gradual improvement on the exercises making up the three modules of VAV over the course of the remediation. Similar to the results in previous reports of successful remediation (Caviola, Mammarella, Cornoldi, & Lucangeli, 2009; Klingberg, Forssberg, & Westerberg, 2002a), visuospatial working memory and emotion recognition were enhanced through training, further suggesting that VAV acts on the cognitive constructs tested during the evaluations. Only the weighted scores on "disgust" did not increase during the program (illustrated by a lack of correlation between the weighted score and session number). This exception can be explained by the introduction of the figurative meaning of *disgust* during the two last sessions. For example, a person can be "fed up with," or "disgusted by," an event or a belief, as opposed to a rotten taste or odor. It is thought that children younger than 9–10 are not generally able to understand the semantic meaning of *disgust* at greater than guessing levels, despite being able to recognize the facial features (Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000). These items were removed from VAV subsequent to this pilot study.

Although this pilot study shows that VAV has considerable potential as an intervention tool for working with children with developmental delay, it has some important limitations. First, given that the study was completed in a school setting, we were limited in our contact with participants' families, which hindered our ability to collect pre- and postremediation behavioral and psychological data on our participants. While the participants' medical records were screened for well-known developmental and genetic disorders (i.e., autism, Fragile X), we were unable to obtain a reliable parent-report measure of the impact of VAV on participant behavior. Second, we were especially limited in the time we had with the patients at Time 2, 6 months after the end of the remediation. Ideally, we would have collected all of the measures from Time 0 and Time 1 to further compare the time points. Third, although this was a pilot study, with the simple goal of verifying the adaptive level and format of VAV, it still would have been useful to collect data from a comparison group. Future studies of VAV should include multiple diagnostic groups to fully estimate the impact of the software on participants' behavior and cognition, as well as a control condition that quantifies the generic effect on participants of participating in an intervention. Fourth, though understandable for such a time-intensive project, our sample size was relatively small for drawing reliable statistical conclusions. Although we did not detect effects of gender and IQ on our results, it is likely that our sample size was simply too small to draw conclusions about the impact of the participants' characteristics on the data. Future studies should aim for multiple and more robust groups. Fifth, it was difficult to measure the impact of practice effects on measures administered at Time 0, Time 1, and Time 2. Finally, the outcome measures used at the evaluation time points, and especially the experimental emotion-recognition task, afforded limited transfer to real-world social settings. Future studies may want to consider alternative methods for evaluating socioemotional competence in a naturalistic way.

In conclusion, the VAV program is very promising. All participants were able to use the training program, suggesting that the difficulty level of VAV is appropriate for individuals with

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moderate mental retardation. Moreover, VAV represents a potential, and badly needed, solution for targeting specific cognitive weaknesses in children who demonstrate weaknesses in working memory, socioemotional skills, or face processing, such as those exhibited by children on the autism spectrum. Future studies combining neuroimaging with programs like VAV will inform us about the neural substrates underlying these improvements and the neurobiology of changing neural networks. As research improves and our ability to understand cognitive impairments and learning problems evolves, it is important to bring research to practice by developing nonprofit educational materials that are easily accessible to practitioners and parents of affected individuals.

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Received 3/15/2011, first decision 1/18/2012, second decision 6/4/2012, accepted 5/1/2012.
Editor-in-Charge: Tony Simon

The first two authors contributed equally to the study. The authors thank the participants and their families as well as the team at the Centre Baron at the Office Médico-Pédagogique for their valuable assistance and Mr. André Decroux, Inspector Claude Chomety, and Dr. SamiaAllaoua in particular. We are also grateful to Andreas Posada for his help during the programming stage of VAV. This work was made possible by grants from the Eagle Foundation, the Fondation Handicap Mental &Société (FHMS) of Geneva, the Fondation 1796 and the Fondation Dora, and the University of Geneva's Centre Interfacultaire de Neurosciences.

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