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# FACE AND EMOTION RECOGNITION BY ADHD AND NORMAL ADULTS

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## SUMMARY

### Background:

To compare speed, speed variability and accuracy during feature integration, frontal, profile and upside-down face recognition, as well as identification and matching of emotions in facial expression, in ADHD and normal adults.

### Material/ Methods:

Four subtests from the Amsterdam Neuropsychological Test (ANT) and the Emotional Continuous Performance Test (ECPT) were applied in 50 ADHD and 50 normal adults.

### Results:

ADHD adults took significantly longer than the controls to select the feature, face and emotion displayed, for both ANT and ECPT tasks. There was no statistical difference between the ADHD and control group for accuracy in ANT tasks, while during ECPT tasks the ADHD adults demonstrated less accuracy than the control group.

### Conclusions:

These results for the speed and its variability showed that both ANT and ECPT can be used efficiently as additional objective diagnostic procedures for the evaluation of ADHD in adults, whereas for accuracy, ECPT seems to be more discriminative than the standard ANT.

**Key words:** facial expression, feature integration, processing speed, mimicry

## INTRODUCTION

Follow-up studies of childhood Attention-Deficit/Hyperactivity Disorder (ADHD) have indicated that 10% to 60% of cases persist into adulthood (Weiss et al., 1985; Mannuzza et al., 1993). A review of the literature supports the validity of this diagnosis in adults (Faraone et al., 2000; Wilens et al., 2004) and indicates a prevalence of approximately 4% (Kessler et al., 2006; Wilens et al., 2004), or 2.9% for narrowly-defined ADHD and 16.4% for broadly-defined ADHD (Faraone & Biederman, 2005). Untreated adult ADHD can be associated with antisocial behavior, substance abuse, and poor functioning in educational, occupational, and socioeconomic domains (Kessler et al., 2006; Spencer et al., 1994). Persons with ADHD change jobs more frequently (Barkley et al., 1996; Weiss & Hechtman, 1993), and attain lower occupational rank (Mannuzza et al., 1991). It has been reported (e.g., Serfontein 1994; Weiss & Hechtman 1993) that adults with ADHD continue to present with attention problems, often choosing occupations requiring little or no attention to detail. According to Wender (1997), adults with ADHD continue to have attentional difficulties that tend to manifest themselves in personal relationships and academic pursuits; they often report problems with short term memory, distractibility and impulsivity. Legal problems are more common in this population as well (Barkley et al., 1996; Hansen et al., 1999; Mannuzza et al., 1991). Neuropsychological research has been aimed at identifying consistent markers of cognitive dysfunction in ADHD (Taylor & Miller, 1997; Aron et al., 2003; Castellanos et al. 2006; Castellanos & Tannock, 2002) and neuropsychological deficits have been documented in several studies (Arcia & Gualtieri, 1994; Downey et al., 1997; Epstein et al., 2001; Holdnack et al., 1995; Lovejoy et al., 1999; Schweiger et al., 2007; Seidman et al., 1998; Silverstein et al., 1995; Weyandt et al., 1998). Reaction time studies in the area of information processing and attention provide ample evidence that processing speed is a sensitive parameter in the experimental and clinical evaluation of (neuro) psychological functions (De Sonneville, Njokiktjien & Bos, 1994; Wiersema et al., 2006). The results reported by Williams (2007) highlight the importance of fluctuations in cognitive performance in ADHD, and suggest that there may be independent sources of variation, with inconsistency affecting the fast and slow portions of the reaction time (RT) distribution.

Accurate interpretation of information derived from facial expression is a prerequisite for successful nonverbal communication, but speed of processing is equally crucial, as personal communication proceeds on a real-time-basis. Facial expressions may change very rapidly and consequently impose high demands on a person's processing capacity. When time restrictions during assessment are absent or when deficits are subtle, differences, deficits, or both in facial information processing may not be observed at the accuracy level, while they would possibly show up at the level of speed of processing. Therefore, speed of facial information processing may facilitate discrimination between normal and impaired processing of faces and facial emotions. Slow

processing of facial information may seriously hamper social communication and its development. In ADHD, poor social skills, behavioral problems, and impaired interpersonal relationships have been hypothesized to be secondary to impaired reception of nonverbal communication (Pelc et al., 2006). Simultaneously, an important aspect of such reception is face recognition and the identification of facial expressions. In this respect, correct decoding of emotional facial expressions seems particularly important (Carton et al., 1999). For instance, Rapport et al. (2002) have shown that adults with ADHD perform worse than controls on tasks involving affect recognition, in contrast to those involving the recognition of non-affective stimuli. It may be, then, that difficulties with the appropriate identification and decoding of emotions prevent individuals with ADHD from developing adequate social and communicative behavioral patterns. Positive emotions are not only recognized first, but also more accurately than negative emotions (de Sonnevile et al., 2002; Everhard, Shucard & Shucard, 2001; Markham & Wang, 1996; Michalson & Lewis, 1985, Philippot & Feldman, 1990; Tremblay, Kirouac & Dorea, 1987; Walden & Field, 1982).

The identification of individual facial expressions has been associated with partially separable neural systems. Overall, facial expressions of emotion are associated with activation of the medial prefrontal cortex, consistent with its role in the more general aspects of appraising and monitoring emotion (Lane et al., 1997; Phan et al., 2001; Williams et al., 2005).

A search of the literature on behavioral parameters during face and emotion recognition in adults with ADHD shows that there has been little research directly in this area. Most studies have focused on children with ADHD (Markham & Adams, 1992; Singh, 1998; Yuill & Lyon, 2007; Pelc et al., 2006; Katz-Gold et al., 2007; Corbett & Glidden, 2000). For example, the findings of Fonseca et al. (2009) suggest that emotion processing difficulties in children with ADHD extend beyond facial emotion, and also affect the recognition of emotions on the basis of contextual information. Thus these data indicate that children with ADHD have an overall emotion-processing deficit.

The object of our study was to compare the behavioral parameters (speed, speed variability and accuracy) between ADHD and normal adults during face recognition and identification of facial emotions, using tasks from the Amsterdam Neuropsychological Test (ANT), and matching emotions with the Emotional Continuous Performance Test (ECPT). We hypothesized that ADHD adults would need more time to process facial and visuo-spatial information, and would have a higher error rate than controls.

## **METHODS**

### **Subjects**

Some 50 ADHD patients (29 males, 21 females, mean age = 33.4; SD = 8.39) and 50 healthy controls (24 males, 26 females, mean age = 29.13; SD

= 8.32) participated in this study. There were no statistically significant differences of age between the two groups. Of the ADHD adults, 35 were diagnosed according to DSM-IV and referred for participation in this study by their psychiatrists, while the other 15 were self referred and diagnosed with ADHD while participating in the study. To receive the diagnosis, the participants needed to have a positive history of ADHD in childhood and to currently meet DSM-IV diagnostic criteria. In terms of clinical sub-types, 32 of them were predominantly inattentive, 6 had predominantly impulsive/hyperactive symptoms, and 12 had a combined type. However, for our purposes they were considered together and analyzed as a unified ADHD group, without subtyping according to DSM-IV. The ADHD adults were tested and recorded at the Praxis für Kind, Organisation und Entwicklung in Chur, Switzerland. The normal adults were recruited via announcements in the media and from the Medical University and Academy of Sciences and Arts in Skopje. All subjects had normal or corrected to normal vision. All clients were individually assessed with neuropsychological and neurophysiological testing in an environment free from distractions. Only the administrator was present during the testing. All subjects were tested in two sessions (one neuropsychological and one neurophysiological assessment), which lasted approximately 2.5 hours each. All participants gave informed consent. The subjects were not allowed to take any medication in the 48-hour period prior to testing.

### **Procedure**

In the first assessment the following set of interviews and questionnaires was used to confirm or exclude ADHD:

- Current and Childhood Symptoms Scale (Barkley);
- Brief Symptom Inventory (Derogatis);
- Health History (Barkley);
- Trauma Questionnaire (Müller & Thomann);
- Semi-structured Interview for Adults with ADHD (Barkley).

Then a neuropsychological assessment was performed, consisting of ten tasks from the Amsterdam Neuropsychological Tasks (ANT 3.0, de Sonneville, 1999, [www.antprogram.nl](http://www.antprogram.nl)).

The following exclusion criteria were applied:

- no history of head injury with loss of consciousness;
- no neurological or systemic medical disease (e.g. epilepsy, diabetes);
- no current use of drugs or alcohol;
- no current migraine;
- no comorbid psychotic psychiatric disorder.

During the second session, all subjects underwent QEEG recording with a Mitsar 21-channel QEEG system during the Emotional Continuous Performance Test – ECPT (Psytask), using a two-stimulus Go/NoGo paradigm with a duration of 20 min. First, all subjects were given a number of practice trials in order to be sure that they were able to carry out the tasks without making

an unacceptably high amount of errors because they did not understand the task instructions or had forgotten the target signal. Every subject was instructed to respond as accurately and as quickly as possible.

### Tasks

The assessment included ten tasks from the Amsterdam Neuropsychological Tasks program (ANT 3.0, De Sonneville, 1999) and the Emotional Continuous Performance Test (ECPT, Meier, Müller & Kropotov, 2007). The measures used for the present study were part of a series of studies investigating aspects of neuropsychological and neurophysiological functioning among those groups. Of the ten ANT tasks, only four that were suitable for the topic of this paper were analyzed. The subjects were seated at a table at a distance of 80 cm from the computer screen.

*Task 1: Baseline speed (BS).* In this task, a white fixation cross is displayed in the center of the computer screen, and then changes into a white square after a random time interval (Figure 1). When this change occurs, the participants should press the mouse button with their index finger as fast as possible, after which the cross returns and this sequence repeats itself. The task consists of 10 practice trials and 32 real trials for each hand, starting with the non-dominant hand, followed by the dominant hand. This task is known to measure simple speed, which requires minimal cognitive demands (mere detection of a stimulus change) and can therefore be used as a measure for simple automated motor reaction time. The post response interval, or PRI (period between response and next stimulus onset), varied randomly between 500 and 2500 ms to prevent anticipation strategies. The following two main outcome measures were analyzed:

1. Speed. Median reaction times (RTs) for baseline speed (in ms; averaged over both hands) were calculated as an index of speed of information processing.
2. Speed variability. Within-subject standard deviations of RTs of baseline speed (averaged over both hands) were calculated as a measure of speed variability (variability of performance).



Figure 1. Display for baseline speed (BS) task. The cross (left) is a fixation point and the square (right) is the target

*Task 2: Feature integration (FI).* After memorizing a predefined visuo-spatial feature (a 3x3 matrix containing six white and three red squares), the subjects have to detect this feature in sets containing four features. When the target feature is present, a “yes” response is required, otherwise a “no” response. The task consists of 80 trials, of which 50% are target trials. There were two different conditions. In one condition, all patterns in the display set looked very similar to the target. This makes the recognition of the target rather difficult (“difficult” condition). There were 40 such display set presentations, each requiring a response (i.e., 40 trials). Half of these contained the target pattern, requiring a “yes” response (target trials). The other half required a “no” response (non-target trials). In the other condition (also consisting of 40 trials), the patterns in the display set were quite dissimilar to the target, which makes target detection easy (“easy” condition): the target just pops up like a Gestalt among the alternative patterns (see Figure 2). The target that had to be kept in mind was presented only at the beginning of the task. The display set was presented until the subject pressed a key; that is, presentation time was variable and equals the reaction time. Measures of speed (mean reaction times and the standard deviations of the correct responses) as well as of accuracy (number of errors) were obtained for all of the four trial types (difficult target, difficult non-target, easy target, and easy non-target).

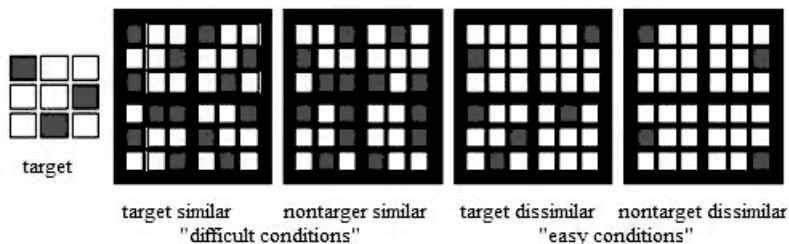


Figure 2. Signal types used in the Feature Integration task. The “yes” key should be pressed on target signals and the “no” key on nontarget signals



Figure 3. Example of a target face (in the middle) and display set in the face recognition task (frontal, profile and upside-down faces)



Figure 4. Example of signals used in the Identification of Facial Emotion task. Target emotions are respectively (left to right): happy, sad, angry, and afraid

*Task 3: Face recognition (FR).* The subject had to discover a target face in a display set that consisted of four faces. Both the target face and the faces in the display set were four digitized high-quality color photos of human faces (“frontal,” “profile” and “upside-down,” neutral expression, Figure 3), taken from a set of pictures of 20 different persons (boys, girls, adult men and women) all dressed in the same black T-shirt to control for differences in non-facial features. Preceding each signal, a probe (the to-be-recognized face) is presented for 2.5 s. The gender and age category (children, adults) of the probe and signal always match, that is, when the probe is a girl’s face, the signal contains the pictures of 4 girls, and so forth. The subject should press the “yes”-key when the probe is present (20 trials), and the “no”-key when this is not the case (20 trials). The target face was presented for 2,500 ms and then disappeared from the screen. After 500 ms, it was followed by a display set, which, as in the FI-task, remained on the screen until the subject pressed a key. Measures of speed (mean reaction times and standard deviations of the correct responses) and accuracy (number of errors) were obtained for target and non-target trials.

*Task 4: Identification of facial emotions (IFE).* In this task the subject is asked to decide whether a face shows a specific (“target”) expression (“yes” key) or an expression different from that one (“no” key). The signal consists of one digitized photo of a face showing an expression that can be identified as happy, sad, angry, or afraid (examples in Figure 4). The total stimulus set consists of 32 pictures from 4 different persons, each showing the four emotions. The task consists of 4 parts of 40 trials. In each part, half of the trials contain the target emotion, whereas in the other half a random selection of the four other emotions is presented.

### ECPT

The ECPT task for the Mitsar system, constructed and validated by Meier, Müller, and Kropotov (2007), is a modified Go/NoGo task. This task is a relatively new test, with limited use till now (Markovska-Simoska & Pop-Jordanova, 2009). In this task, stimulus material was taken from the set of pictures



Figure 5. Stimuli for the ECPT task (see explanation in the text)

of facial affect by Ekman and Friesen (1976), and consisted of black and white slides of the faces of female and male actors, each presenting an angry, happy, or neutral face. In this task (Figure 5), trials consisted of the presentation of a pair of stimuli with an inter-stimulus interval of 1.1sec. Four categories of trials with the following facial expressions of emotions were selected: Angry-Angry, Angry-Happy, Happy-Happy, and Happy-Neutral+Sound. The trials were grouped into four sessions with one hundred trials each. The trials were presented randomly.

This task can be considered as analogous and comparative to the matching of facial expressions task used by de Sonneville et al., (2002), because the subject has to press the button with the index finger of the dominant hand as fast as possible every time an angry face is followed by an angry face (Go-condition = matching) and to withhold pressing on the other three trial conditions (NoGo-condition = mismatching). The speed and speed variability were calculated through reaction time on the Go condition and the variation of the reaction time, while accuracy rate was measured in reference to omission errors or misses on the Go condition and commission errors or false alarms on the three NoGo conditions.

### **Statistical analysis**

Statistical analyses were performed using Statistica 7.0 software. A series of multivariate General Linear Models (GLM) was conducted to compare adults with ADHD to healthy controls, on the various outcome variables of BS, FI, FR, IFE and ECPT tasks. The results per task were evaluated by analyses of variance (ANOVA), with separate runs for speed (reaction time), speed variability and accuracy (percentage of errors) as dependent variables, with group type, age and gender as between-subjects factors, and the various task manipulations as levels of within-subject factors in a repeated measurement design.



In addition, direct (within-subject) comparisons between tasks were carried out to investigate differences in speed of processing visuo-spatial information, neutral faces, and facial emotions.

Cluster analysis (K Mean classification algorithm from the Statistica 7.0 software package) was used to divide ADHD subjects into three groups on the basis of the ECPT performance.

## RESULTS

### Baseline speed

ANOVA analysis showed that there was no significant difference in baseline speed [ $F(1, 97) = 3.033, p = 0.085$ ] and variation of speed [ $F(1, 97) = 1.561, p = 0.214$ ] between ADHD and normal adults. This indicates that adults with ADHD were not significantly different from the control group in terms of their basic ability to use the response key or basic attention to the task.

### Feature integration

Figure 6 (left) shows that processing of nontarget “similar” and target “similar” was slower in the ADHD group [ $F(1, 98) = 11.39, p < 0.001, F(1, 98) = 7.180, p < 0.009$ ]. Furthermore, the processing of target “dissimilar” was more difficult [ $F(1, 98) = 7.632, p < 0.007$ ], compared to non-target “dissimilar” [ $F(1, 98) = 3.433, p < 0.067$ ]. Also, the ADHD group showed higher variability of the reaction time for both “similar” [ $F(1, 98) = 3.673, p < 0.05$ ] and “dissimilar” [ $F(1, 98) = 4.550, p < 0.035$ ].

As regards accuracy (Figure 6, right), the miss rate was higher than the false alarm rate, differences being largest for “similar”, but this was not significant between groups [ $F_{\text{miss similar}}(1, 98) = 1.194, p < 0.277, F_{\text{miss dissimilar}}(1, 98) = 2.768, p < 0.099, F_{\text{false alarms similar}}(1, 98) = 0.530, p < 0.468, F_{\text{false alarms dissimilar}}(1, 98) = 0.003, p < 0.960$ ].

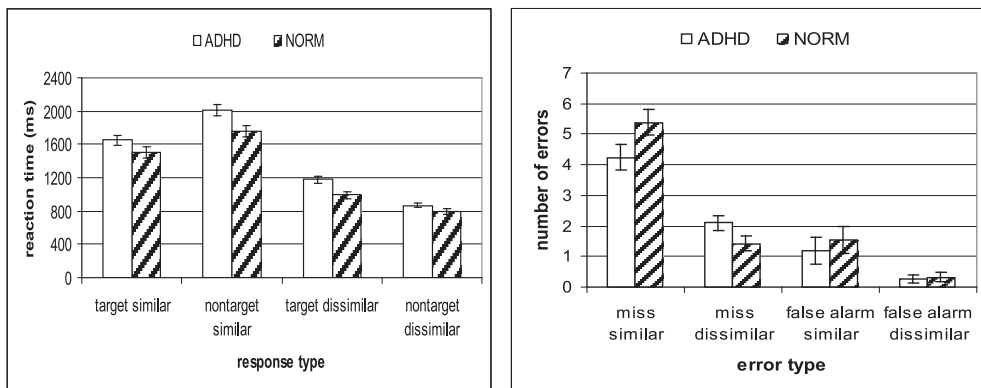


Figure 6. Speed (left) and accuracy (right) of feature integration

### Face recognition (frontal)

The ADHD group was slower than normal controls in reaction time for hits [F (1, 95) = 18.44,  $p < .000$ ], and for reaction time with correct rejections [F (1, 95) = 11.72,  $p < .001$ ; Figure 7 left]. Variation of reaction time was significantly higher in the ADHD group for both hits [F (1, 95) = 14.25,  $p < .000$ ] and correct rejections [F (1, 95) = 6.873,  $p < .000$ ] compared to healthy controls (Figure 7 right). All subjects made more misses than false alarms, but the difference between the groups was not significant [ $F_{\text{misses}}$  (1, 95) = 0.204,  $p < .653$ ,  $F_{\text{false alarms}}$  (1, 95) = 2.407,  $p < .124$ ; Figure 8].

### Face recognition (profile)

Regarding speed, all ADHD subjects needed more time than controls in the target condition (hits) [F (1, 93) = 9.266,  $p < .003$ ] and in the non-target condition (correct rejections) [F (1, 93) = 7.416,  $p < .008$ ; Figure 7 left]. Variation of reaction time was significantly higher in the ADHD group for both hits [F (1, 93) = 8.962,  $p < .004$ ] and correct rejections [F (1, 93) = 7.126,  $p < .009$ ] compared to healthy controls. With respect to errors, all subjects made more misses than false alarms, but the difference between the groups was not significant [ $F_{\text{misses}}$  (1, 93) = 0.234,  $p < .630$ ,  $F_{\text{false alarms}}$  (1, 93) = 0.173,  $p < .678$ ; Figure 8].

### Face recognition (upside-down)

This part of the task was the most difficult for the subjects, and here the differences between the groups were more prominent. As expected, the ADHD group was slower than normal controls in reaction time (Figure 7, left) for hits [F (1, 93) = 10.90,  $p < .001$ ], as well as for reaction time for correct rejections [F (1, 93) = 9.131,  $p < .003$ ]. Variation of reaction time was significantly higher

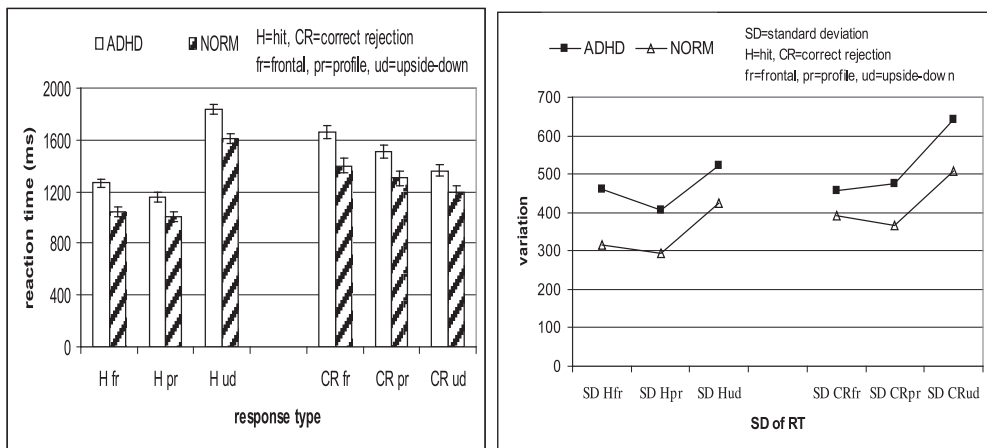


Figure 7. Reaction time (left) and variation of reaction time (right) in the face recognition task for frontal, profile and upside-down faces as a function of group type

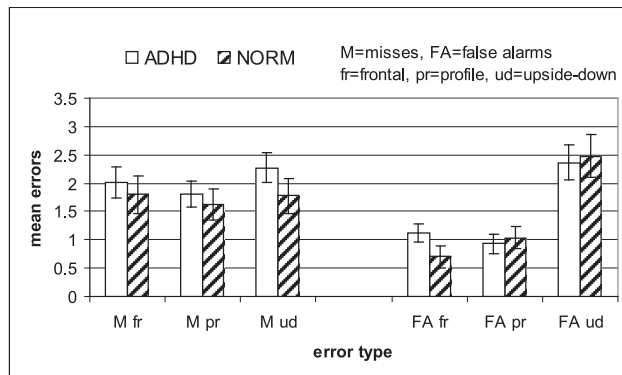


Figure 8. Accuracy of face recognition task for frontal, profile and upside-down faces as a function of group and response/error type

in the ADHD group for both hits [ $F(1, 93) = 4.573, p < .035$ ] and correct rejections [ $F(1, 93) = 5.753, p < .018$ ] compared to the healthy controls (Figure 7 right). All subjects made more misses than false alarms (Figure 8), but the differences between the groups were not significant [ $F_{\text{misses}}(1, 93) = 0.434, p < .234, F_{\text{false alarms}}(1, 93) = 0.067, p < .796$ ].

### Comparisons between the parts of the FR task

The analysis of reaction time and its variation for hits and correct rejection revealed that speed decreases on the third and most difficult part (upside-down faces) of this task in both groups [ $F_{\text{RT hits (fr/pr/ud)}}(2, 293) = 18.27, p < .000$ ]; [ $F_{\text{RT CR (fr/pr/ud)}}(2, 293) = 17.13, p < .000$ ]; [ $F_{\text{SD hits (fr/pr/ud)}}(2, 293) = 12.42, p < .000$ ]; [ $F_{\text{SD CR (fr/pr/ud)}}(2, 293) = 14.16, p < .000$ ]. As regards accuracy, task type interacted with false alarm rate, which was much higher for upside-down faces [ $F_{\text{FA (fr/pr/ud)}}(2, 293) = 29.29, p < .000$ ], while there were no differences between misses and task type [ $F_{\text{M (fr/pr/ud)}}(2, 293) = 2.031, p < .133$ ].

### Identification of facial emotions

Reaction time (Figure 9, left) of “yes”-responses for happy faces were almost identical in both groups [ $F_{\text{happy}}(1, 95) = 0.317, p < .575$ ], while in the other three parts of the task ADHD subjects were significantly slower for “yes” [ $F_{\text{sad}}(1, 95) = 4.160, p < .044, F_{\text{angry}}(1, 95) = 8.257, p < .005, F_{\text{fear}}(1, 95) = 20.41, p < .000, ;$ ] and “no” responses [ $F_{\text{happy}}(1, 95) = 5.093, p < .026, F_{\text{sad}}(1, 95) = 13.21, p < .000, F_{\text{angry}}(1, 95) = 4.960, p < .028, F_{\text{fear}}(1, 95) = 18.94, p < .000$ ; Figure 9 left] for all four parts of the task. This was concomitant with higher variation of reaction time (Figure 9 right) for “yes” and “no” responses in the ADHD group [ $F_{\text{SD CR happy}}(1, 95) = 3.887, p < 0.024, F_{\text{SD hits sad}}(1, 95) = 8.847, p < .004, F_{\text{SD CR sad}}(1, 95) = 5.465, p < .021, F_{\text{SD hits angry}}(1, 95) = 9.775, p < .002, F_{\text{SD CR angry}}(1, 95) = 20.29, p < .000, F_{\text{SD hits fear}}(1, 95) = 21.58, p < .000, F_{\text{SD CR fear}}(1, 95) = 11.37, p < .001$ ], except for the SD of “yes” hits for the happy faces [ $F_{\text{SD hits happy}}(1, 95) = 1.655, p < 0.201$ ].

As far as accuracy is concerned, the number of misses for all tested emotions among the two groups was not significantly different [ $F_{M \text{ happy}}(1, 95)=0.885, p<.349, F_{M \text{ sad}}(1, 647)=4.160, p<.423, F_{M \text{ angry}}(1, 95)=1.159, p<.284, F_{M \text{ fear}}(1, 95)=0.931, p<.337$ ], versus more false-alarm errors for happy, sad and angry faces in the ADHD group [ $F_{FA \text{ happy}}(1, 95)=4.048, p<.047, F_{FA \text{ sad}}(1, 95)=9.113, p<.003, F_{FA \text{ angry}}(1, 95)=6.076, p<.015$ ]. The number of false-alarm errors was higher in the normal group for afraid faces, but this difference was not significant [ $F_{FA \text{ angry}}(1, 95)=1.837, p<.0179$ ] (Figure 10 left).

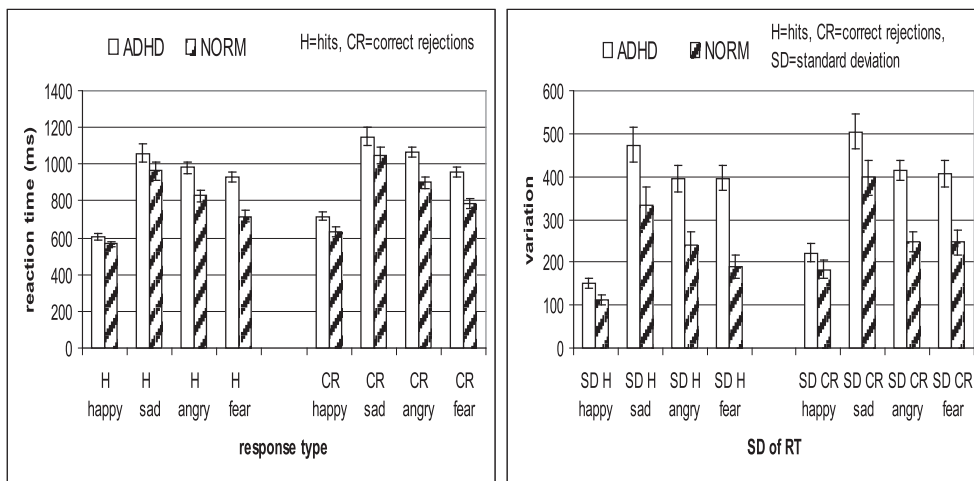


Figure 9. Reaction time (left) and variation of RT (right) during IFE. H=hits, CR=correct rejections, SD=standard deviation

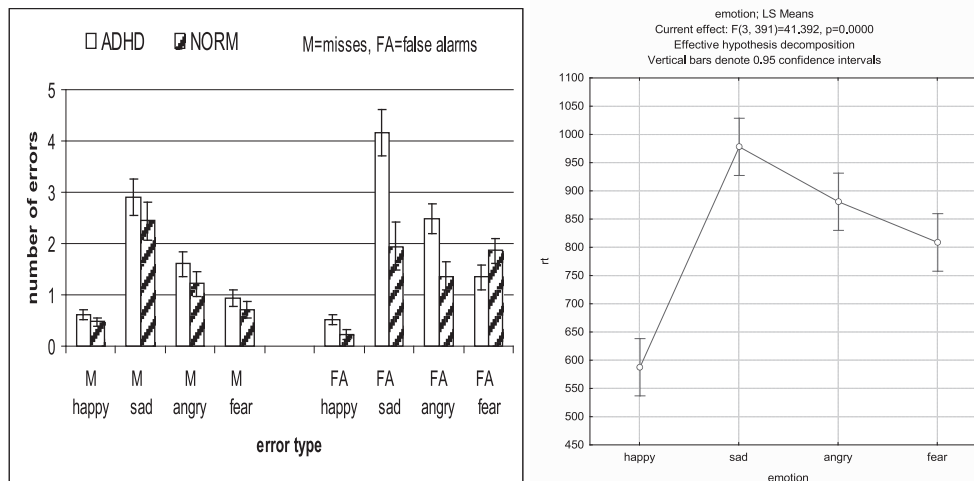


Figure 10. Error type (left) and difference of RT (right) between the four parts of the IFE task

### Comparisons between the parts of the IFE task

When accuracy was compared between the two groups for the four parts of the IFE task, recognizing a positive emotion (in this case happy faces) had the smallest number of misses and false alarms, while recognizing the sad face had the highest numbers of misses and false alarms, [ $F_{\text{misses (h/s/a/f)}} (3, 390)=31.139, p<0.000$ ;  $F_{\text{false alarms (h/s/a/f)}} (3, 391)=26.68, p<0.000$ ] (Figure 10, left). Speed varied with the type of emotion, as identifying a “happy” face was much faster than the other (negative) emotions [ $F (3, 391)=41.392, p<0.000$ ] (Figure 10 right). Gender and age differences were nowhere significant.

### ECPT

The ADHD group was slower in processing the ECPT task, with higher reaction time compared to the control group [ $F (1, 87)=4.731, p<0.032$ ]. Also, RT variation was higher, as expected, in the ADHD group [ $F (1, 87) =27.00, p<0.000$ ]. Regarding accuracy, opposite results from the ANT task were obtained: namely, in the ECPT task the ADHD group made more misses [ $F (1, 87)=25.17, p<0.000$ ]. The ADHD group made more commission errors on happy-happy faces [ $F (1, 87)=6.036, p<0.016$ ], while there was no group effect for commission errors on angry-happy and happy-neutral faces (Figure 11).

Cluster analysis (K Mean classification algorithm from the Statistica 7.0 software package) was used to divide the ADHD subjects into three groups on the basis of ECPT performance. Indices of reaction time, variation of reaction time, inattention (the number of omissions of target stimuli) and impulsivity (the number of false alarms) were taken into account. Analysis of variance was used to assess the differences in ANT performance between the three clusters. As follows from Table 1, the subjects in the first cluster ( $n=17$ ) performed the test most successfully, i.e. with the lowest numbers of go omissions and erroneous responses to no-go stimuli pairs, shorter reaction time, and smaller variation of reaction time. In the third cluster ( $n=9$ ), the numbers of omissions of target stimuli and erroneous responses to non-relevant pairs were the highest, the reaction time was longer, and variation was the highest.

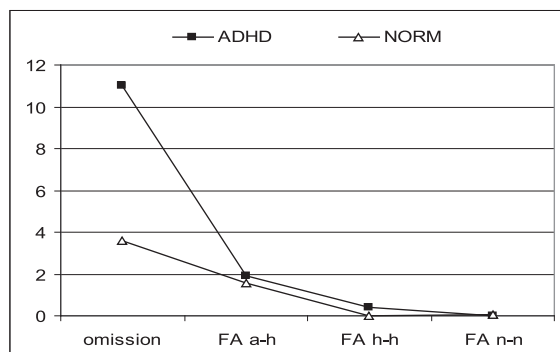


Figure 11. Error type in ECPT (FA-false alarms, a-angry, h-happy, n-neutral)

Table 1. Cluster analysis of the ADHD adults according to ECPT accuracy of performance

Performance results	Group I	Group II	Group III
Reaction time	375±20.74	435±23.93	527±32.03
Variation of reaction time	10.2±2.74	12.6±3.3	19.0±4.2
Omissions of relevant trials	4.11±2.52	13.25±3.26	31.22±5.63
Erroneous responses to non-relevant trials	1.44 ±1.88	1.70±2.31	2.08±2.76

The subjects in the second cluster (n=24) were characterized by intermediate numbers of omissions and erroneous responses.

**Performance data for ADHD clusters during the FR and IFE tasks**

If we look at the results of the performance data during the FR and IFE tasks in the three ADHD clusters according to the ECPT, we can see that this cluster analysis is a good discriminating factor, since group III (which had the highest number of omission and commission errors) also had poorer performance on the ANT task compared to groups I and II (tables 2 and 3). However, the difference is statistically significant only for misses [ $F(6,88)=4.682, p<0.014$ ] and false alarms for FR [ $F_{\text{frontal}}(6,88)=4.928, p<0.011$ ], RT and SD RT for the “happy” part, and “no” responses RT for the “angry” part of the

Table 2. Performance data for face recognition in the three ADHD clusters

FRONTAL						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	1.206	373	1.580	436	1.23	0.76
Group II	1.243	427	1.619	449	1.96	0.75
Group III	1.460	571	1.733	470	4.11	2.33
PROFILE						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	1.118	355	1.450	421	1.43	0.94
Group II	1.109	362	1.416	466	2.00	0.65
Group III	1.305	516	1.738	538	2.66	2.00
UPSIDE-DOWN						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	1.266	355	1.742	421	1.82	1.96
Group II	1.334	362	1.811	466	2.08	2.29
Group III	1.463	516	1.862	538	3.77	3.22

Table 3. Performance data for identification of facial emotions in the three ADHD clusters

HAPPY						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	536	106	642	155	0.52	0.41
Group II	606	132	705	209	0.54	0.77
Group III	730	262	800	282	0.66	0.94
SAD						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	881	326	1.083	510	1.66	3.54
Group II	1,093	512	1.141	508	2.23	3.88
Group III	1,098	454	1.165	505	3.45	4.44
ANGRY						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	877	383	944	347	1.41	2.04
Group II	965	352	1.033	394	1.41	2.41
Group III	1.015	388	1.260	518	1.88	3.66
AFRAID						
Measure	RT	SD (RT)	CR	SD (CR)	M	FA
Group I	847	368	881	395	1.17	1.00
Group II	882	345	929	374	0.65	1.43
Group III	1.072	477	977	343	1.37	2.00

IFE. From the numbers in the tables it can be seen that performance decreases proportionally to the qualification to the group.

### Comparisons between tasks

#### *Feature Integration versus Face Recognition*

Comparisons between RT for target “similar” in the FI versus RT for hits in the FR show that the processing speed is significantly slower during FI pattern recognition than face recognition in frontal and profile faces [ $F_{FI/FR\ fr} (2, 94)=9.102, p<0.000$ ;  $F_{FI/FR\ pr} (2, 92)=6.676, p<0.002$ ], while in upside-down faces there was a small difference [ $F_{FI/FR\ ud} (2,92)=3.145, p<0.048$ ]. As expected, only the upside-down faces were more difficult to recognize, and because of that speed in FR upside-down is slower (almost similar) than speed in FI. This result suggests that featural and configural strategy formation is not a constituent process of the FI task only, but also in the FR upside down (Figure 12 left). The opposite was found to be true in comparing correct rejections for “similar” targets [ $F_{FI/FR\ fr} (2, 94)=8.176, p<0.001$ ;  $F_{FI/FR\ pr} (2, 92)=6.359, p<0.003$ ,  $F_{FI/FR\ ud}$

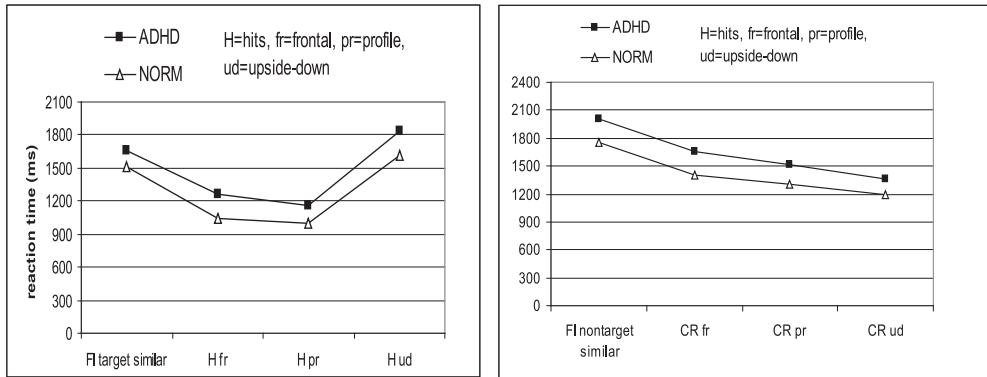


Figure 12. Reaction time of feature and face recognition as a function of group and task type during hits “similar” (left) and correct rejections “similar” (right)

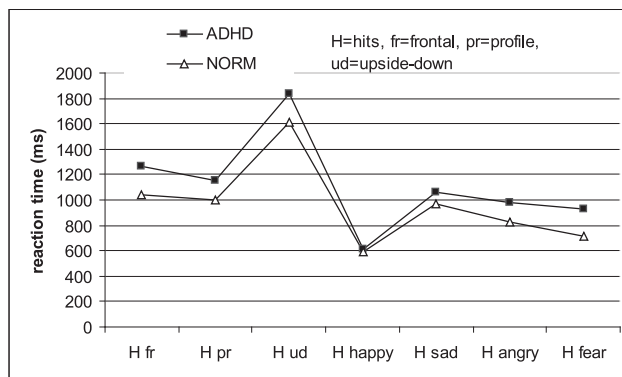


Figure 13. Reaction time for “yes” hit responses during face recognition and identification of facial emotions

(2,92)=6.897,  $p < 0.002$ ], indicating that detecting a non-target between “similars” was faster for upside-down faces, compared to features, with frontal and profile face in between (Figure 12 right). With respect to accuracy, signal type interacted with task type, and the miss rate was larger for feature integration compared to face recognition (see Figure 6 right and Figure 8 left).

#### Face Recognition versus Identification of Facial Emotions

As can be seen in Figure 13, speed varied with the type of task, and analysis showed that face recognition was slower than identification of facial emotions [ $F(7,88)=7.6507$ ,  $p < 0.000$ ], with upside-down and sad as the most difficult cases. In all parts (except happy faces), the ADHD group was slower than controls.

Gender and age did not affect performance in any of the tasks.



## DISCUSSION

As predicted, adults diagnosed with ADHD were found to be generally slower and, especially, more variable in their speed of information processing than the control group. Interestingly, these differences between groups were greatest on tasks that demand cognitive effort (i.e. all except baseline speed). These tasks require controlled information processing, with a combination of complex memory search and execution as a result of decision processes. The results suggest that specific information processing deficits are present in ADHD adults (slower reaction time and greater fluctuation of reaction time) during feature integration, face recognition, and identification and matching of facial emotions tasks.

Response speed variability yielded the most significant differences between ADHD adults and the control group. This finding is consistent with the study by Kalff et al. (2005), who reported significant differences in the fluctuation of speed in tasks for focused, divided and sustained attention, between children with ADHD and children with no or other pathology. This extreme variability in response latencies is one of the most robust findings reported for older children with ADHD (Paule et al., 2000). Various explanations have been proposed, such as lack of consistent effort (Kuntsi et al., 2001; Oosterlaan & Sergeant, 1996), characterizing the core deficit as a state regulation deficit (in line with, e.g., Börger & Van der Meere, 2000; Sergeant et al., 1999). State regulation is the ability of the organism to change from a current non-optimal arousal or activation state in the direction of an optimal (target) state to fulfill task requirements (Hockey, 1997), while effort is the energy necessary for the regulation of the organism's actual state. An alternative explanation is that ADHD is characterized by impairment in time perception, and more specifically the precise representation of temporal information, leading to an inability to predict precisely the point in time when an impending stimulus event requires a fast response, thereby causing variable response times on all reaction time tasks (Paule et al., 2000). An intriguing model has been proposed that links working memory (a key component underlying executive functions associated with *control* of motor processes, also playing a central role in time perception), with impairments in behavioral inhibition (which is thought to cause less efficient executive functioning). Neuroimaging studies have found abnormalities in brain morphology in ADHD in those brain regions (e.g., cerebellum, basal ganglia, and frontostriatal circuitry) that subservise time perception, as well as executive functioning (Aylward et al., 1996; Berquin et al., 1998; Casey et al., 1997). In addition, Stuss et al. (2003) have demonstrated that lesions in the frontal lobes (with the exception of the ventral medial-orbitofrontal region), particularly in adults, impair the stability of behavior and led to increased intra-individual variability. When ADHD is viewed as a predominantly frontal-subcortical disorder, our findings of extreme variability of response speed during controlled information processing are consistent with this view.

Specifically, the results of the visuo-spatial task (feature integration) show that the processing of “similar” was very slow in both groups, but this was more pronounced in the ADHD group. The results we obtained are very consistent with the results of De Sonneville et al. (2002), who pointed out that the search for features between “similar” requires highly demanding, effortful, controlled information processing, suggesting the use of a featural processing strategy. In contrast, processing of “dissimilar” was fast, suggesting a configural, more automatized processing strategy, in that target features are easily spotted between “dissimilars,” and non-target signals are quickly rejected, as none of the included elements contain more than one solid block. The reaction time for correct rejections was greater than the reaction time for hits in both groups, reflecting the fact that non-target signals require exhaustive processing, whereas processing of target signals can be terminated when a match has been found.

As regards the face recognition processing task, there is significantly longer reaction time in ADHD compared to norms, and no difference in misses and false alarms. The speed decreases and variability increases when the task becomes more difficult. Thus the upside-down faces are most difficult ones to recognize, and this decreases facial processing capacity. The results suggest that ADHD adults had the same accuracy level, while lagging behind considerably in reaction time and variation. While most objects are somewhat harder to recognize upside-down than right-side up, inversion makes faces dramatically harder for normal adult subjects to recognize (Valentine, 1988). Face recognition and object recognition appear to depend on different systems, which are anatomically separate, functionally independent, and differ according to the degree of part decomposition used in representing shape. But upside-down faces do not engage the face-specific processing mechanisms. This was shown by Farah’s (1996) experiment, in which a prosopagnosic subject had an impaired face processor, which was engaged by the upright, but not the inverted faces. This was also found in our study, where we obtained very similar results for performance in FI and FR of upside-down faces.

Many studies have reported significantly faster responses to happy than sad faces, demonstrating that healthy adults recognize facial expressions of positive emotions (e.g., happy) faster than expressions of neutral or negative emotions (e.g., sad, angry, or disgusted) (Schulz et al., 2007; de Sonneville et al., 2002; Grimshaw et al., 2004; Leppanen & Hietanen, 2004). Also, no significant differences were evident in emotional facial expression decoding accuracy between children with ADHD and control children for happiness and disgust, while for decoding of angry and sad facial expressions, accuracy in ADHD children was significantly lower (Pelc, 2006; Czaplewska, 2008). Consistent with this research, in the ANT IFE task we used, recognizing the happy faces was easier for both groups, while in recognizing a sad, angry, or afraid face, the ADHD group was significantly slower in reaction time for hits and for correct rejections; however, there were no differences in misses and false alarms.

To identify a facial emotion, subjects are required to match the signal with an internal representation of the target emotion. Apart from decoding the signal, performance also depends on the quality of these internal representations, which are thought to be impaired in ADHD.

Remarkably, the ADHD adults could not be distinguished from the healthy controls by their accuracy on all ANT tasks. The exception for error rates in our study was the ECPT (Go/NoGo) task, where there was a high number of omission errors (as a measure of inattention, Corkum and Siegel, 1993) in the ADHD group and no differences in false alarms (as a measure of inhibition) between groups. This result is in line with the findings on 5-6-year-old children (Kalff, 2005). The explanations for these findings could be low sustained attention during longer periods of time, or the more complicated structure of the ECPT (it can be considered as a condensation of the FR and IFE ANT tasks). Also, ECPT has been demonstrated to be a more difficult task than VCPT (visual continuous performance test - with animals as target stimuli and plants as nontarget stimuli) (Markovska-Simoska & Pop-Jordanova, 2009).

Moreover, with cluster analysis it was possible to divide all the ADHD adults into three groups, depending on the quality of test performance:

- (1) adults with slight deviations from the norm, who made the fewest go trial omission errors (less than 6.54%) and erroneous responses in no-go trials (less than 1.35 %);
- (2) adults with moderate deviations, who made 12.97% go trial omissions and 1.47% erroneous responses in the no-go trials;
- (3) adults with a severe attention disorder (around 31.67% and more omissions of go trials) and high impulsivity (more than 2.09% erroneous responses in the no-go trials).

In this study, we have revealed a direct dependence of speed, speed variability and accuracy during ANT feature integration, face recognition and identification of facial emotions tasks on the severity of the attention disorder and impulsivity level in the examined group of adults with ADHD syndrome. Thus, in adults from the first group, who made the fewest errors, the values for speed, speed variability and accuracy were the lowest, whereas adults in the third group (with the strongest attentional disorder) had poorer performance (higher values for speed, speed variability and accuracy). The results showed that these behavioral parameters obtained during ANT and ECPT tasks can be used as an additional objective diagnostic procedure for adult ADHD.

The present study found no gender and age differences in speed, speed variability or performance. No gender differences in performance were also reported by Schulz et al., (2007).

There is one limitation to be mentioned related to generalization to other populations. Specifically, the present sample was relatively well educated compared with the general population of persons with ADHD, who are known to achieve lower formal education and occupational status than adults without the disorder (Manuzza et al., 1991).

## CONCLUSIONS

In general, we can conclude that the ADHD group showed a greater response time and larger variability of reaction time than the control group, but there was not a significant difference in error types, with the exception of ECPT task, where significantly more omission errors were registered. It has also been shown that differences in performance quality increase with task complication and duration.

Accordingly, the ADHD group showed more difficulties of dealing with complexity tasks involved recognition of faces and facial expressions. In addition, the decoding of complex visual information, and of emotional states, is not straightforward, since the different feelings of individual participants may influence the visual decoding and decision-making processes.

This study was designed to evaluate speed and accuracy of processing of faces that varied in features, orientation, and emotional expression in adults with and without ADHD. Analyses focused on four subtests from the Amsterdam Neuropsychological Test (ANT) and an Emotional Continuous Performance Test (ECPT). Results showed that across a range of measures, adults with ADHD performed slower and more variably than their non-ADHD counterparts, but generally had similar error rates, except on the ECPT. Based on these data, we can conclude that ANT along with ECPT have proven to be efficient and sensitive neuropsychological tests. Both speed and speed variability in processing abstract non-facial, facial identity, and facial affect information are sensitive parameters in distinguishing adult ADHD from normal, while accuracy depends on the task complication and duration.

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