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Improving autism screening in French-speaking countries: Validation of the Autism Discriminative Tool, a teacher-rated questionnaire for clinicians' use

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ABSTRACT

Background: Autism screening remains a major challenge in most French-speaking countries. Two main issues contribute to this problematic situation: unavailability of tests in French and psychometric/ methodological weaknesses of existing instruments. These shortfalls result in late and inadequate referrals to autism specialist clinics, jeopardising both children's diagnosis and prognosis. This article describes the validation of the Autism Discriminative Tool (ADT), a teacher-rated level-two screener for children aged two to six years. It demonstrates how the ADT specific properties may help reduce actual screening challenges and improve referrals' adequacy to tertiary autism diagnostic services.

Method: ADT items were prospectively tested in a community-based group (n = 118), children with autism spectrum disorders (ASD; n = 90) and non-ASD children presenting mimicking conditions such as intellectual disabilities, language impairments and various psychological disorders (n = 36). Children in the clinical samples were rated by their teacher at the beginning of a diagnostic assessment process within three specialised autism clinics.

Results: results suggest that a 26-item version performs well as a stage-two screening device, with theoretical sensitivity rate of 0.83, specificity of 0.94 and an overall correct detection rate of 86.5%. Using different cut-off scores categories, results illustrate how inadequate referrals may be avoided as 44% of non-ASD children scored negatively on the questionnaire prior to their evaluation.

Conclusions: based on blind teachers' ratings, the ADT appears to be a good complementary device to help French-speaking clinicians identify preschoolers needing multidisciplinary ASD diagnostic assessment.

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1. Introduction

Autism spectrum disorders (ASD) screening devices are used at different levels of a health care system. First level tests aim at detecting possible ASD in the general population. They are typically used by primary care professionals such as general practitioners or paediatricians when a child fails to reach core developmental milestones. First level tests focus on sensitivity, that is detecting true positive cases. To achieve this goal, their content is relatively broad in order to minimise risks of under detection. Level-two screening tools are used in specialist/ second level care settings (e.g. by child neurologists/ psychiatrists or clinical psychologists) when a child shows atypical development or screened positive at level one. Focusing on specificity, they are tailored to discriminate various developmental disorders from possible ASD (detection of true negatives). To achieve this differential screening function, their content is very detailed to minimise risks of over detection. Challenges of second level tests consist of presenting high specificity value while preserving acceptable sensitivity. In countries where a two-stage screening system prevails, children who screen positives are often referred to tertiary autism services where the diagnostic will either be confirmed or dismissed.

1.1. Shortfalls and limitations of actual ASD screening tools

Although a range of tools are currently available, lack of adequate screening remains a reality for many countries (Mandell et al., 2010; Radecki, Sand-Loud, O'Connor, Sharp, & Olson, 2011; Sheldrick, Maye, & Carter, 2017; Zwaigenbaum et al., 2015). Two issues seem to contribute to this situation internationally: underuse and weaknesses of existing instruments.

Underuse of ASD screening tests is a major public health problem. In the USA, the level of screening practice remains low (Dosreis, Weiner, Johnson, & Newshaffer, 2006; Radecki et al., 2011; Sand et al., 2005) despite official recommendations (Filipek, Accardo, & Ashwal, 2000; Johnson & Myers, 2007; Self, Parham, & Rajagopalan, 2015). The situation is similar in Europe, with a lack of cohesion regarding autism screening procedures and an absence of official recommendations in the majority of the Union members, including Belgium (Garcia-Primo et al., 2014). When health professionals are questioned about the absence of ASD detection within their practice, numerous arguments are given (Dosreis et al., 2006; National Audit Office, 2009; Sand et al., 2005; Gura, Champagne, & Blood Siegfried, 2011; Barton, Dumont-Mathieu, & Fein, 2012; Crais et al., 2014; Soto et al., 2014). Financial costs are deemed repellant in countries where a system of private funding prevails. Human cost is identified as another limitation while lack of adequate test translation concerns non-English speaking countries. Health professionals also evoke a fear of falsely alarming the parents and/or to stigmatise the child. Lack of knowledge about ASD characteristics complete this list of arguments.

Beyond the lack of screening, researchers have identified multiple biases inherent to detection instruments, especially concerning psychometric and methodological aspects. These shortfalls can further explain screening underperformances in the domain of autism spectrum disorders. In general, the question of sensitivity is mainly relevant to first level detection devices. Because of their primary selective function, they tend to over-identify a number of children at risk of ASD. This over-selectivity particularly applies to preterm babies (Moore, Johnson, Hennessy, & Marlow, 2012) and children with motor, visual or auditory impairment (Luyster et al., 2011). The question of specificity applies to second-level detection instruments. Those devices need robust specificity but several replications have highlighted lower than expected levels in young children (Allen, Silove, Williams, & Hutchins, 2007; Oosterling et al., 2010).

Particular methodological aspects may further affect the quality of screening tests. These limitations concern both the initial validation studies and their replications (Brereton, Tonge, Mackinnon, & Einfeld, 2002; Barbaro & Dissanayake, 2012; Charmann et al., 2007; Chlebowski, Robins, Barton, & Fein, 2013; Camarata, 2014; Moore et al., 2012; Miller et al., 2001; Norris & Lecavalier, 2010; Ozonoff et al., 2018; Soto et al., 2014; Taylor, Vehorn, Noble, Weitlauf, & Warren, 2014; Vostanis, Smith, & Corbett, 1994; Zwaigenbaum, 2011). Shortfalls include biased and/or limited size-samples (e.g. absence of control group), selection bias, lack of cohort follow-up after initial screening, replications in different contexts, absence of cultural adaptation, translations that do not follow recommended guidelines and lack of correspondence with the DSM-5. Other shortcomings include eventual requirement for informants' training, lengthy administration time, restricted test coverage in terms of symptoms, age, intellectual and developmental levels. Bias in parental recall and limitation of symptoms detection in very young children add to difficulties encountered nowadays with ASD screening.

1.2. ASD screening limitations: consequences on a Belgian Autism Reference Centre

In Belgium and France, the government has set up "Autism Reference/Resources Centres" (ARC). The main objectives of these third level highly specialised teams are to confirm suspicion of ASD and to perform complex differential diagnoses. Existence of the ARC is supposed to improve and fasten the diagnosis process of ASD and therefore interventions. However, these goals are regularly challenged by a lack of prior screening at lower levels of the healthcare system. This results in two major issues encountered by our team and many other across Belgium and France: late and inadequate referrals.

Despite the existence of early detection tests and an improvement in autism awareness, ASD diagnosis remains tardy (Centers for Disease Control & Prevention, 2007; Renty & Roeyers, 2006). Late diagnosis is problematic since it delays individual interventions and family support. This difficulty is commonly encountered by our ARC team, with only 19% of children being well under three years of age at time of referral. Children between three and six years roughly constitute 39% of our referrals, meaning we also diagnose older children, adolescents and even adults.

Furthermore, lack of detection results in a proportion of children and adults being inadequately and excessively addressed to tertiary autism services, even when they do not even display sufficient signs to raise concerns about the disorder. Inadequate referrals

Table 1
Summary of main ASD screening tools and their characteristics.

	Age[1]	Main Raters[2]	Teacher rating	DSM-5 based	French version
Level 1 tools (focus on sensibility)					
FYI (Reznick, Baranek, Reavis, Watson, & Crais, 2007)	12 M	P1			
M-CHAT (Robins et al., 2001)	18-30 M	P1,P2			X
M-CHAT-R/F (Robins et al., 2014)	16-30 M	P1			X
ESAT (Swinkels et al., 2006)	16-30 M	P1, P2			
CAST (Scott, Baron-Cohen, Bolton, & Brayne, 2002)	4-11 Y	P1			
Level 2 tools (focus on specificity)					
STAT (Stone, Coonrod, & Ousley, 2000)	24-36 M	P2			
SCQ (Rutter et al., 2003)	> 4 Y	P1			X
ASSQ (Ehlers, Gillberg, & Wing, 1999)	6-17 Y	P1	X		
PDDST-II (Siegel, 2004)	18-48 M	P1			
GARS-3 (Gilliam, 2013)	3-22 Y	P1	x	x	
BISCUIT (Matson et al., 2009)	17-37 M	P1			

Where: (1) M = months and Y = years (2) P1 = parents and P2 = health care professionals.

swell the numbers of individuals on the waiting lists, with most Belgian and French families having to wait anything between seven months and two years before their child can benefit from a full multidisciplinary assessment. Inadequate referrals also contribute to diagnoses' delays for those who truly have ASD. This is obvious in our team, where only 39% of the 2010′ referrals received an ASD diagnosis by the end of the evaluation procedure. These numbers are way too low for a third-level service as prior possibilities of diagnoses exist, for example by second level clinicians. With an increase in ASD awareness over the years, diagnostic proportions naturally reached a mean value of 56% between 2012 and 2013. To further improve the situation, we have started to organise pre-assessment appointments in order to quickly evaluate the possibility of ASD. This solution has significantly reduced the problem of referral inadequacy to our team, with an increase of ASD diagnoses reaching 81% in 2016. This strategy demonstrates that prior screening by general/specialists child practitioners is paramount. However, our team is now spending precious time performing first and second-stage triage/screening rather than concentrating on expert diagnostic work.

1.3. Necessity of a French ASD screener for level-2 practitioners

If we are to improve ASD screening in Belgium and other French-speaking countries, some measures are to be taken both locally and nationwide. Beyond the necessity to inform and advice health providers about the procedures to be followed, we need to ensure that screening devices are available in French, culturally adapted, adapted to specific informants, match DSM-5 criteria and demonstrate good psychometric properties.

As seen in Table 1, most screening measures are available in English. The Modified Childhood Autism Test (M − CHAT; Robins, Fein, Barton, & Greene, 2001) and its revised version (M − CHAT-R/F; Robins et al., 2014) are the only level-one screeners available in French. They are both considered gold standard for ASD screening, although the 2014 version is significantly better at detecting children with possible ASD. Therefore, tailoring another instrument intended for primary care settings is unnecessary. At level two, the Social Communication Questionnaire (SCQ; Rutter, Bailey, Lord, & Berument, 2003) is the only instrument with a French counterpart (Kruck, Baduel, & Rogé, 2013). This tool is therefore theoretically suitable for use in French-speaking countries. Alternatively, other second level instruments could be translated. However, we dismissed the possibility of simply translating current tests from English to French for the multiple reasons described below.

First, several studies support evidence for cultural differences in the expression of autistic traits across continents and countries, jeopardising use of screeners internationally (Albores-Gallo, Roldan-Ceballos, & Villareal-Valdes, 2012; Carruthers et al., 2018; Inada, Koyama, Inokuchi, Kurada, & Kamio, 2011; Seif Eldin, Habib, & Naefal, 2008; Soto et al., 2014; Thabtah, 2017). Theoretically, this shortage may apply to instruments tailored and validated in countries such as the US, the UK or even northern Europe where cultural norms diverge from French culture. If cultural aspects affect respondents' rating, item modifications may be required before translation and a new validation process is to be expected.

Secondly, we wanted our tool to be specifically designed for teachers' rating as they have been shown to be excellent informants when it comes to identify possible ASD traits in children (Gabovitch & Curtin, 2009; Hanson et al., 2013; Kanne, Abbacchi, & Constantino, 2009; Nissenbaum, Tollefson, & Ruse, 2002). Unfortunately, none of the existing screening tools has been exclusively tailored to collect their observations despite researches demonstrating that item rating is influenced by informants' function/roles in the child's life (Azad & Mandell, 2016;Dillenburger, Keenan, & Doherty, 2010; Hurtig et al., 2009; Nordhal-Hansen, Kaale, & Ulvund, 2013). This is particularly the case when teachers do not have the opportunity to observe specific behaviours within the school setting or do not possess highly personal information as included in the SCQ (e.g. item questioning language regression). This element constitutes another motive to dismiss translation of an existing tool.

Beyond cultural and informants centred issues, none of the current instruments has been designed according to the DSM-5 except for the GARS-3 (Gilliam, 2013). As other researchers, we believe that being tailored according to the DSM-IV may affect devices' reliability (Thabtah, 2017; Volkmar & Reichov, 2013). For example, most of the screeners strongly emphasise socio-communicative

behaviours whilst including very few items relating to stereotyped behaviours. When present, these items mainly refer to general motor or rigid functioning. Lack of reference to the DSM-5 criteria implies the omission of sensory related items which have been proven to be highly specific to ASD (Baranek, Boyd, Poe, David, & Watson, 2007; Baranek, David, Poe, Stone, & Watson, 2006; Hilton, Harper, Holmeskueker, & Runzi Lang, 2010; Carlier et al., 2017; Stanciu & Delvenne, 2016). In our opinion, this specific shortfall undermines detection performances.

To summarise, the fact that existing tools do not meet essential criteria of cultural, teacher and DSM-5 adaptation demonstrates that items amendments are paramount before considering French translation. Unfortunately, adding, retrieving or rephrasing original items would modify the screeners' internal structure and norms so that original psychometric values would no longer be valid. Furthermore, translation and even new validation of actual instruments do not address and reduce methodological biases such as cohort follow-up, prospective methodology or absence of gold standard instruments to corroborate children's diagnoses after initial screening. For example, French validation of the SCQ only included ASD children and a cohort of typically developing children. No other clinical cohorts were examined, meaning that this version no longer corresponds to the definition of a level-two screener. In addition, several replication studies suggested poor predictive power in preschool children (Allen et al., 2007; Corsello et al., 2007; Eaves, Wingert, & Ho, 2006; Oosterling et al., 2010). The authors themselves confirmed a better precision of their tool with older children (Rutter et al., 2003), meaning that the SCQ is not the best option to screen those attending nursery schools. As a result, French-speaking countries do not have access to level-two screeners for this age-range. Furthermore, translation of the only DSM-5 based screener GARS- 3 is not a viable option due to particular methodological shortfalls such as its mixed mode methodology (e.g. retrospective validation, partially web-based), use of jargon that can cause item misinterpretation in teachers, difficulty of its rating scale in a school setting or heterogeneity of compared cohorts (Atlas, 2017; Hutchins, 2017; Karren, 2017).

In the light of these different matters, we chose to construct our own test instead of translating an existing instrument. This strategy allowed for cultural and teachers adaptation, inclusion and increase of DSM-5 related items as well as reduction of many methodological biases.

1.4. The Autism Discriminative Tool (ADT)

The initial version of the ADT is a simple behavioural checklist, with no screening purposes. Its development was based on a retrospective and exploratory study comparing behavioural profiles of children with ASD to mimicking and/or overlapping conditions (Carlier et al., 2017). Now available as a second level screener, the ADT combines two objectives (Table 2). Beyond the general purpose of detecting children needing ASD assessment, both goals were chosen to directly address issues of late and inadequate referrals encountered by autism diagnostic services.

Our device targets children between two and a half to six and a half years old suspected of ASD due to the display of developmental difficulties or at an increased risk due to the presence of ASD in close family members. It comes under the form of a behavioural repertoire composed of 35 items that are illustrative but non-exclusive of ASD symptoms. Twenty-six items out of 35 are considered critical and used for screening purposes whilst the entire 35-item version constitutes the clinical description of the child within the school setting. Each item has a precise and clear definition illustrated by several examples, so to ensure respondent maximum understanding and to avoid items overlap.

For research purposes, the version used in the validation study is divided into four parts exploring social deficits, communication difficulties, repetitive functioning (e.g. motor stereotyped behaviours, excessive/non-functional routines, strong attraction to details…) and sensory peculiarities (Table 3). Those items are combined in the final version to include two parts -socio-communicative deficits and repetitive/stereotyped behaviours- to reflect the DSM-5 format.

The ADT is intended to be completed by mainstream nursery teachers (= raters), based on their daily observations of the child in the last two months prior to completion survey. Its completion takes less than five minutes and requires no former training. The rating is based on a 0–1 point scale depending on the reported presence or absence of abnormal behaviours, with possible total scores ranging from 0 to 26. Once completed by the teacher, the ADT is returned to the clinician (= user) who scores and interprets it according to specific cut-off score ranges.

Table 2
Main objectives of the ADT.

Objective 1	*Objective 2*
Detection of children with other developmental disorders or psychological conditions (specificity)	Detection of children with a suspicion of ASD
▼	▼
Avoiding referrals of false positively screened children to tertiary autism diagnostic services	Earlier Referrals of true positively screened children to tertiary autism diagnostic services
Consequences on issues encountered by ARC	*Consequences on issues encountered by ARC*
Reduction of inappropriate referrals	Reduction of age at referrals
▼	▼
Reduction of waiting lists	Earlier diagnoses and interventions

Table 3
Experimental version of the ADT.

Part 1. Socialisation (9 items)
1. Reduced or absent social use of eye contact.
2. Reduced or absent response to social smile.
3. Reduced or absent diversity of oriented facial expressions.
4. Social isolation, aloneness.
5. Reduced or absent spontaneous approaches towards peers.
6. Negative or neutral response to peer approaches.
7. Socially inappropriate approaches.
8. Reduced or absent social play/group play.
9. Lack of showing objects to share interest, lack of enjoyment to share with others.
Part 2. Communication (8 items)
10. Absence of pointing to share interest.
11. Absence of proximal pointing.
12. Inability to follow people's pointing.
13. Reduced or absent imitation of others' actions.
14. Absence of verbal language. Less than 5 words used consistently.
15. Reduced or absent use of gestures to communicate.
16. Repetitive verbal language. Immediate or differed echolalia.
17. Atypical tone of voice. Monotonous/flat intonation.
18. Lack of reciprocal conversation.
Part 3. Stereotyped behaviours (9 items)
19. Alignment/classification of objects according to specific criteria.
20. Hand/finger repetitive movements, fidgeting.
21. Stereotypic use of objects.
22. Hand flapping.
23. Rocking when standing or sitting.
24. Tiptoe walking.
25. Excessive and rigid attention to details.
26. Negative reactions to changes or new settings. Strong adherence to non-functional routines.
27. Over-focused, limited and /or unusual interests.
28. Objects twisting.
Part 4. Other (8 items)
29. Reduced or absent imagination. Lack of variety in pretend play.
30. Overreaction to auditory stimuli.
31. Hyporeaction to auditory stimuli.
32. Food selectivity.
33. Emotional dysregulation.
34. Atypical treatment of visual information such as peripheral vision.
35. Atypical treatment of visual information such as eyes squinting.

2. Method

2.1. Participants

The clinical sample consisted of 126 children ranging from 30 months to 78 months of age, assessed for ASD at three autism reference centres. Children were categorised into two groups according to their final diagnosis: ASD or non-ASD. Ninety children belonged to the ASD group, with a predominance of boys. The non-ASD group included 36 children with intellectual disability (ID; n = 16), language impairment/delay (n = 15) and various psycho-affective disorders (n = 5). There was a community-based comparison group composed of 118 typically developing children attending mainstream nursery school in Brussels. In the control group, boys and girls were represented in equal proportions, with a mean age of 57 months (Table 4).

Children in the clinical sample came from three autism reference centres: the Hopital Universitaire des Enfants Reine Fabiola (Brussels, N = 101), the Cliniques Universitaires Saint-Luc (Brussels, N = 13) and the Centre Hospitalier de Versailles in France (Paris, N = 12). Participants assessed at the Children's Hospital were systematically included into the study between November 2013

Table 4
Characteristics of participants.

Participants (N)	ASD (90)	Non-ASD (36)	Control group (118)
Boys (%)	75 (83)	33(92)	59 (50)
Girls (%)	15 (17)	3 (8)	59 (50)
Mean age (months)	49 ± 11.15	50 ± 11.13	57 ± 11.12
Mean IQ	83 ± 19.26 (N = 22)	N/A	N/A
Mean DQ*	42 ± 12.89 ± (N = 63)	N/A	N/A
ADT mean score	16.82	11.11	0.81

* DQ = developmental quotient.

and June 2016, according to their arrival order. Children from other teams were recruited during the academic year 2015-2016. Six mainstream control schools, chosen at random, accepted to participate into the study. However, only four followed the whole data collection procedure and provided us with valid questionnaires. These four schools were spread across Brussels, therefore ensuring representation of children from all racial/ethnic background. To be included in the study, all children had to attend a mainstream nursery school on a regular basis. Children in the clinical sample needed a clear diagnosis by the end of the multidisciplinary diagnostic assessment. Those with a genetic condition explaining the autism symptomatology ("syndromic autism") were excluded from the study.

Parents of children in the clinical group were informed of the study and the voluntary aspect of their participation at the very beginning of the diagnostic assessment process. They received full assurance that results would be published without identifying information and received a detailed information sheet with the contact information of the main researcher. All parents who agreed to the study signed a consent form. In the control group, parents were informed by teachers during group or individual class meetings. The study received full ethical approval from the respective Ethics Committees of the participating hospitals and the Université Libre of Brussels.

2.2. Screening measures

In the clinical sample, the ADT was rated by the child's teacher at the beginning of the diagnostic assessment procedure to ensure blind rating. In agreement with criteria for ADT administration, teachers knew the children for at least two months prior to answering the ADT. The checklist did not mention the term "autism" or "autism spectrum disorders" and was returned during the second or third evaluation appointment.

2.3. Diagnostic measures

All children from the clinical group were assessed with the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, Dilavore, Risi, & Rogé, 2008) and the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, Le Couteur, Rogé, & Fombonne, 2011). Both ADOS and ADI-R were administered by certified staff, blind to the ADT results. Cognitive functioning was assessed whenever possible and depending on the tests' availability in French. Non-verbal tests included the Leiter International Performance Scale (Leiter, 1979), Leiter-R (Roid & Miller, 1997) or non-verbal Wechsler (NVW; Wechsler & Naglieri, 2009). Although dated, the original Leiter was chosen due to its suitability for children unable to indicate their answer by pointing as requested by other non-verbal tests. Results were converted according to the norms of the revised version, available from the tests' editor (Roid & Miller, 1997). Comprehensive intellectual testing included the Wechsler Intelligence Scale for Pre-schoolers (WPPSI-III; Wechsler, 2005) and the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2004). Newest versions of the Wechsler were unavailable in French at time of assessments. IQ testing was supplemented by developmental assessment using either the Brunet-Lézine Revised (BL—R; Brunet & Lézine, 2001) or the Psycho-Educative-Profile-Revised (PEP-R; Schopler, 1994). This PEP version was chosen over its newer version as it allows for a full developmental quotient. Decision of an ASD diagnosis was reached by the autism reference centre multi-disciplinary team, independently of the research team. Diagnostic was based on positive scoring on both ADOS and ADI-R, clinical observations and judgments as well as agreement between all members of the team.

2.4. Data analyses

Descriptive analysis consisted in a comparison of ADT profiles across groups, in an attempt to identify potential discriminative and non-contributive items. While most analyses compared ASD to non-ASD children, scores from sub-groups were also scrutinised in order to maximise the understanding of the questionnaire's discriminative power. Detailed statistical analysis was obtained using the Statistical Package for Social Sciences (SPSS 23). The first step was to perform tests of Student to investigate group differences on the ADT total screening score. This was followed by several discriminant function analyses (DFA) to identify which ADT items were most predictive of an ASD diagnosis. Independent variables corresponded to ADT items while the two clinical groups were the dependent variables. Finally, ranges of cut-off scores were determined by analysing score distributions among groups.

3. Results

3.1. Descriptive analysis

Most children from the control group scored particularly low on the questionnaire's entire version while the ASD sample scored above 12 points in 84% of cases. The majority of the non-ASD sample scored at an intermediate level. Analysis of item ratings across groups (Table 5) suggested that key characteristics of children with ASD included poor eye contact (item 1), isolation (item 4), lack of play with peers (item 8) and lack of reciprocity (item 9). Communicative gestures were rarely used (item 15) despite the absence of verbal language (item 14). Stereotyped behaviours most commonly observed were: intolerance to change (item 26), flapping (item 22) as well as hypo and overreaction to sounds (items 31 and 30). In the non-ASD sample, reduced or absent group play (item 8) and lack of symbolic play (item 29) were the most common characteristics. One child out of two in the control group was deemed rather isolated (item 4) but approaches towards peers seemed more frequent than in the ASD group (item 5). Flapping (item 22) was less frequent than in ASD (22% versus 42%). Frequency of hyper-reaction to sounds was rated at 33% whereas the hypo-reaction was

Table 5
Percentage of children in each group who failed individual item.

Item	Failed items		
	% in ASD group (n = 90)	% in non-ASD group (n = 36)	% in the control group (n = 118)
1	69	56	6
2	62	25	7
3	39	39	4
4	78	50	5
5	68	50	1
6	27	25	3
7	50	39	2
8	86	67	3
9	82	50	0
10	59	36	0
11	70	36	0
12	60	42	2
13	58	33	4
14	80	50	0
15	70	44	1
16	29	28	4
17	11	22	5
18	18	14	3
19	34	17	2
20	32	6	0
21	40	17	2
22	42	22	0
23	23	11	1
24	20	8	0
25	31	25	2
26	49	47	3
27	38	33	3
28	22	6	0
29	81	61	4
30	48	33	6
31	54	19	4
32	40	25	3
33	32	39	1
34	34	22	3
35	35	17	2

considered to be less frequent by teachers. Further scrutiny of sub-groups profiles revealed that the ADT strongly distinguished ASD from language delay/disorders and pycho-affective disorders. On the contrary, distinction between ASD and ID was not as clear. Based on these results, we hypothesised that a number of items were discriminative and found that other items seemed rather confounding such as items 14 (lack of verbal language), 22 (flapping), 29 (lack of symbolic play) or 30 (hypersensitivity to sounds).

3.2. Statistical analyses

A Student test showed that there was a statistically significant difference between our two clinical groups in terms of mean ADT scoring, with $t(124) = 5.15$, $p < .005$ This preliminary hypothesis being confirmed, we then performed a first DFA using the 35 items of our repertoire. Results suggested that ASD related-function was highly significant with $\chi^2 = 68.104$; df 35, $p < .001$. It explained 100% of the variance. However, analysis of canonical discriminant function coefficients highlighted nine items with very low contributive weights. These items related to eye contact (-.055), absence of gestures to communicate (.019), flapping (.032), tiptoe walking (-.012), strong interests for details (-.096), unusual and excessive interests (.048), objects spinning (-.064), lack of symbolic play (.020) and peripheral vision (-.052). In order to improve the specificity rate of our tool, these nine items were discarded for screening purposes. A second DFA was therefore conducted with the 26 remaining items. Again, it confirmed overall study validity,

Table 6
Summary of canonical discriminant functions.

Function	Eigen Value	Percentage of variance	Canonical correlation	Wilk's lambda	Chi-square	Degree of freedom	Significance
1	.892	100.0	.687	.528	70.786	26	.000

Table 7
Student test based on mean score (ADT-26).

	ASD	Non-ASD	*t*-test	Degree of freedom	Significance (*p* value)
ADT-26	12.77	8.42	4.974	124	< .005

with $\chi^2 = 70.786$; *df* 26, $p < .001$ (Table 6) while another Student test further confirmed that difference of mean scores between ASD and non-ASD children was significant (Table 7).

The second DFA correctly classified 75 out of the 90 ASD children and misclassified two of the 36 non-ASD children. In total, 86,5% of original grouped cases were correctly classified. This gave a theoretical sensitivity value of .83 and specificity of .94. Predictive values were then calculated as all screening predictions were compared to final diagnoses. In its final version of 26 screening items, the ADT had a positive predictive power of .97 and a negative predictive power of .69. One-way analysis of variance further confirmed that there was a significant difference between clinical groups based on ADT screening scores with $F = 24.8$, *dl 1,* $p < .005$.

3.3. Identification of cut-off scores

Rather than perform a ROC analysis resulting in a single cut-off score, we chose to construct several cut-off categories based on score distribution amongst clinical groups (Table 8). This procedure allowed for the reflection of the ASD concept as a continuum and maximise the ADT's clinical use. Multiples possibilities regarding cut-off ranges and scores interpretations were analysed and considered. Finally, a highly specific cut-off score of 18 was chosen as the absolute point above which children should be immediately addressed to specialised ASD services for full diagnostic assessment. While very elevated, this cut-off score still identifies up 14% of the ASD sample versus 3% of the non- ASD sample. A total score between 12 and 17 was deemed to reflect high probability of ASD, with nearly half of ASD children scoring in this range. Scores from 11 to 8 reflected medium probability of ASD. In total, scores between 18 and 8 include near to 88% of children with ASD. These scores indicate to clinicians that a specialised autism assessment is paramount.

In terms of false positives, most measurement errors occurred in the medium-risk range, one-third accounted by children with ID combining poor socio-communication abilities and a minimum of two joint stereotyped bodily movements. Fourty four percent of non-ASD children (N = 16) obtained an ADT score situated in the 0–7 low risk range, indicating that they would not have been assessed in our autism clinic if the ADT had been used prior to their referrals. This illustrates how the use of ADT can reduce inadequate referrals to tertiary autism services. In addition, overall results suggest that the ADT reaches its two objectives: successfully identifying children needing further evaluation whilst reducing false positive cases.

Table 8
Number of children scoring at or above each point on the ADT.

ADT total score	ASD (n = 90)	Language + psycho-affective disorders (n = 20)	ID (n = 16)	Non-ASD (n = 36)
1	90 (100)	20 (100)	16 (100)	36 (100)
2	90 (100)	19 (95)	16 (100)	35 (97.2)
3	90 (100)	19 (95)	16 (100)	35 (97.2)
4	88 (97.8)	17 (85)	16 (100)	33 (91.7)
5	86 (95.6)	17 (85)	13 (81.3)	32 (88.9)
6	85 (94.4)	15 (75)	13 (81.3)	27 (75)
7	83 (92.2)	13 (65)	13 (81.3)	25 (69.4)
8	79 (87.8)	10 (50)	13 (81.3)	22 (61.1)
9	74 (82.2)	8 (40)	11 (68.8)	20 (55.6)
10	69 (76.7)	5 (25)	10 (62.5)	15 (41.7)
11	65 (72.2)	3 (15)	8 (50)	12 (33.3)
12	57 (63.3)	1 (5)	8 (50)	10 (27.8)
13	48 (53.3)	2 (10)	8 (50)	9 (25)
14	41 (45.6)	2 (10)	7 (43.6)	9 (25)
15	34 (37.8)	2 (10)	5 (31.3)	8 (22.2)
16	21 (23.3)	1 (5)	4 (25)	5 (13.9)
17	18 (20)	0	3 (18.8)	3 (8.3)
18	13 (14.4)	0	2 (12.5)	2 (5.6)
19	7 (7.8)	0	1 (6.3)	1 (2.8)
20	5 (5.8)	0	0	0
21	3 (3.3)	0	0	0
22	2 (2.2)	0	0	0
23	1 (1.1)	0	0	0
24	0	0	0	0
25	0	0	0	0
26	0	0	0	0

4. Discussion

The aim of this study was to validate the Autism Discriminative Tool as a second level ASD screening instrument. By creating a new tool, we wanted to provide a specific teacher screener for the French (para)medical community. We also aimed at overcoming some of the methodological issues raised in existing instruments and to ensure that our questionnaire matched the DSM-5 criteria. As a level-two instrument, the ADT is not tailored for very early detection which is usually made at primary care level. Our questionnaire specifically targets children attending nursery schools considered susceptible to present an ASD because of an atypical developmental trajectory or the presence of the condition in close relatives.

The checklist was applied to controls and two cohorts of ASD suspected children referred to autism clinics for diagnostic purposes. Results showed that both clinical samples scored much higher on the ADT than the group of typically developing children. Items relating to socio-communicative deficits were among the most frequent in children who end up being diagnosed with ASD. However, specificity of these items was low excepted for those pertaining to social isolation and lack of sharing. Symptoms relating to stereotyped and rigid behaviours were found to be less frequent than in their socio-communicative counterparts but showed to be very discriminative between clinical groups, especially sensory dysfunctions. A closer examination of ADT profiles further suggested that while our instrument might clearly differentiate children with ASD from those with language or psycho-affective difficulties, it might be less able to distinguish ASD from intellectual disability when this latter condition is accompanied by developmental bodily stereotyped movements mimicking an autism-type condition.

Nine ADT items were found to have low statistical weights, ending up being discarded for screening purposes. The remaining set of 26 optimal items was characterised by a combination of 10 positive symptoms and 16 negative symptoms, those latter mainly belonging to the domain of socio-communication. This statistically derived subtest of items was entered into another discriminant function analysis. This DFA correctly classified 75 out of 90 children with ASD and 36 out of 38 children with other developmental disorders or psycho-affective conditions. Selection of the best discriminative items allowed for specificity to reach .94 whilst preserving an acceptable screening sensitivity rate of .83. These results confirm that the ADT is suitable for differentiating ASD children from those with mimicking or overlapping conditions. It reaches its primary objective of detecting true negatives, preventing their unnecessary referrals to tertiary autism services.

A complementary analysis of variance confirmed that clinical groups significantly differed from one another on the ADT mean screening score. In the edited ADT version, 35 items are rated by teachers but only 26 are scored and interpreted by clinicians for screening purpose. Three risk ranges were determined on the basis of item distribution amongst groups. Children who score from the very high to the medium intervals need a comprehensive ASD assessment in order to clarify the question of differential diagnosis and to obtain recommendations for intervention. Based on this study's results, children who score in the low-risk range do not need referral to tertiary autism services. Nevertheless, to avoid misdetections, ADT guidelines strongly advise that children scoring just under the minimum cut-off score (= false negatives) should stay under the continuous surveillance of level-two clinicians. A second administration of the questionnaire and/or subsequent referral is recommended if ASD suspicions persist or if surveillance indicates later emergence of more specific symptoms. Furthermore, we suggest that the ADT should not be used as a stand-alone screening instrument. Indeed, it would probably have better selection properties when used by second level physicians and/or teams as a complementary device to those based on parental and health professionals' ratings.

This study presents a number of limitations that warrant consideration. First, we acknowledge the small size of the non-ASD sample, particularly in the language disorders/delays and psycho-affective disorders groups. Although differences in group sizes were accounted for in the discriminant function analyses, a larger comparison study would probably add valuable information on subgroups characteristics and profiles. Nevertheless, the ADT is designed to determine the probability of ASD versus non-ASD disorders as a whole, rather than the probability of disorders subgroups.

Another issue to consider is the fact that the ADT identified many children with ID as having a possible ASD (false positives). Whilst this may be considered as a bias, such results are understandable. First, these children had gone through our pre-assessment/triage system and were found by expert clinicians to need multidisciplinary assessment. The ADT came exactly to the same conclusion. When considering chosen cut-off scores, the screener performed even better than experts by identifying over 40% of the children not presenting with ASD. Secondly, a closer analysis of these false positives/ID children showed that beyond socio-communicative difficulties, all youngsters presented two or more stereotyped behaviours. As we know, ID and ASD may share common features especially as repetitive behaviours are concerned. Furthermore, the risk of symptom overlap increases with the severity of cognitive deficits (Bodfish, Symons, Parker, & Lewis, 2000; Hartley & Sikora, 2010; Matson & Rivet, 2008). In other words, due to its detection nature, the ADT is bound to pinpoint individuals with autistic features even though they actually have ID. Thus, referring those children to autism reference centres is perfectly appropriate and even recommended. It is at the heart of the differential diagnosis process.

The third issue is the level of teachers' initial training. In Belgium, future teachers receive very limited information on learning disabilities or in psychiatry. Sensibilisation to ASD is not included in official educational programs, meaning that unless a teacher comes across a child presenting the condition, s/he can spend an entire career without knowing about basic features of autistic disorders. As a result, the present ranges in cut-off scores may differ in European countries where students who are studying to become teachers receive valuable information about ASD. Despite this possible bias, our results are deemed valid as they represent the minimal rate of detection when using a teacher rating strategy. They also show that despite the fact that teachers working in ordinary schools are unfamiliar with the autism phenotype, they are able to detect behaviours both diverging from the norm and illustrative of ASD. Validation implicating teachers can even be worth considering as a strength if we hypothesised that trained colleagues would be more efficient at completing the questionnaire.

Other strengths of the study include blind ratings, use of a prospective methodology, heterogeneity of the children' socio-cultural profiles, application of gold standard ASD tests by certified professionals during the diagnostic phase, comparison of the ASD group with children presenting mimicking or overlapping symptoms, inclusion of a cohort of typically developing youngsters, comparison of detection efficacy with an existing validated tool and true estimates of predictive values due to the availability of diagnoses following the initial screening.

5. Implications

The ADT seems a promising tool to screen ASD in high-risk children who are enrolled in mainstream nursery classes. One of its novelty lies in the inclusion of a new important actor in the ASD detection process, by collecting teachers' feedback. As such, the ADT completes both parental and clinicians' reports, improving the child's overall clinical description and understanding. The choice of the targeted group is another crucial element of the ADT's conception, as it covers a maximum of suspected ASD cases. First, young children frequenting nursery schools include toddlers whose ASD diagnosis went undetected earlier because of lack of screening or/and symptoms subtility as well as older ASD children whose symptomatology onset is slower but fully manifests during the preschool years (Bryson et al., 2007; Ozonoff et al., 2018; Saint-Georges et al., 2013; Yaari et al., 2016). Secondly, over 95% of Belgian children are enrolled in nursery schools (Mangez, Joseph, & Delvaux, 2002). This means that the vast majority of children who will be diagnosed with ASD can be found in preschools. Furthermore, the French High Authority for Health has recently recommended to include school teachers in the ASD detection process (Haute Autorité de Santé, 2018). To date, the ADT is the only screening tool to allow for such implementation, as it was specially tailored to meet teacher's reality. The ADT's psychometric properties are other key points for achieving better detection results. Its high specificity rate certainly contributes to reducing false positive cases whilst selecting a satisfying number of children with ASD. This should help reducing the number of inadequate referrals sent to autism diagnostic services.

In that context, we truly believe that second-level clinicians such as child neurologists or child psychiatrists would considerably gain by using this simple and DSM-5 adapted screening tool to support their referral decision to specialised diagnostic teams.

Conflict of interest

The authors declare that they have no conflict of interest.

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Ethics

This research received full approval from the Ethics Commitee of the Hopital Universitaire des Enfants Reine Fabiola (ref.nb.CEH43/12) and the Université Libre de Bruxelles (ref.nb.029/2013).

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