**2. Literature Review**

This section highlights and critically analyses the available autism screening tests developed for the mobile environment. Any educational, awareness, and non-screening apps are excluded from the literature review section. The functionalities of current autism apps are also briefly explained, and their strengths and weaknesses identified. To be exact, a table at the end of this section will provide all relevant details and functionalities of these apps.

**2.1 Common ASD Tests Mobile Applications**

**2.1 Autism and Beyond App**

AaB is a video-based screening app developed in the United States of America (USA) by researchers from Duke University and Apple in order to assist parents in identifying their children’s mental health challenges (anxiety or tantrums) that might relate to autism (Duke University, 2014). Parents above the age of 18 years old with children below the age of six years old can use the AsB app. The app contains seven modules where three of which are questionnaires about family background, parental concerns and child’s temper tantrum. The seven modules consist of 50 questions plus four videos each approximately 30 seconds to detect the child’s emotions. The app is part of a study that has over 2600 participants and is only used to collect data related to the emotional behaviour of young children between the ages of 1 to 6 years old. Even though AaB has achieved seven out of ten ratings by users, it is limited in scope and does not cover a significant portion of ASD cases besides it cannot be used for instant screening (Autism and Beyond, 2017). Moreover, user reviews revealed that the AaB app is time consuming and not an adequate tool for screening all core ASD symptoms as for example RRBs (Duke University, 2014).

**2.2 Asperger Test App**

The AT app was developed with the intention of providing a proper mechanism for adults to identify the possibility of Asperger or autism traits. While the AT app does not provide a formal diagnosis, it does provide guidance to users for understanding their socially related behaviours. Currently, two versions of the app are available; one for adults/adolescence, and one for children. Each version contains fifty multiple-choice questions, which can be a hurdle for users, especially in on a mobile platform such as smart phones. At the end of the test, users are given a score that denotes the chance of having autistic traits (Touch Autism, 2015). The AT app has obtained 3.9 ratings and its user rate is higher than that of the AaB app. Most users found the AT app useful while a few users felt that the questions are somewhat forceful (Asperger Test, 2017). In addition, the AT app has a wider scope than the AaB app, taking into account both young children, adolescences and adults. Shorter versions of the app have been developed, by (Alison et al., 2012) but have not been implemented in mobile environment.

**2.3 Autism and Developmental Disorder screening App (ANDDS)**

ANDDS was developed to evaluate the risk of ASD and other progressive issues among toddlers aged from 6 months to children younger than 3 years old. The app uses a series of Boolean (yes/no) questions that cover the child’s development behaviours at different age stages, (i.e. 6, 12, 15, 18, 24 and 36 months) (Autism Speaks, 2017). Therefore, this app covers only a limited group and ignores a very large portion of the population (children >3 years old, adolescent, adults). The questions developed for the ANDDS app were developed by behavioural scientists involved in ASD. The results of the app display in three different coloured bands. Red is an indication for further medical evaluation, yellow denotes that parents should be more watchful of their child’s behavioural development, and green shows that the child is in accord with their peers in terms of behavioural development. The ANDDS is not a popular screening test among users, however, as it has no rating.

**2.4 Autism Test App**

ATA is a self-awareness app on autism and other related psychological challenges that can be taken by adults and in some cases by parents when conducting the test on behalf of a child. This app was developed for educational and research purposes to identify the common symptoms of autism in adults, and not for clinical diagnostic purposes. The app contains twenty questions, each with three possible alternatives (disagree, sometimes, absolutely), and it then generates a percentage of autism. One of the obvious major drawbacks of the ATA app is the quantification of autism in cases, as seen in the reviews given by users who have already taken the ATA test. For instance, feedback from individuals with a formal diagnosis of autism showed different scores when taking the test, making the result of the ATA questionable. ATA does not have specific questions that cover the complete range of ASD areas (stereotyped behaviour, communication, reciprocal and social interaction). Users have rated this app at 3.3, and a few have commented that the results generated by the app do not make any sense (Autism Test, 2017). It is not clear what the methodology used to design the questions were and whether it is based on known, published, screening methods from behavioural scientists. The ATA app has a translated version in Arabic called Autism Test Light, which has a 2.5 rating and just two user reviews.

**2.5 ASDetect App**

ASDDetect app uses a series of videos and non-videos combined with questionnaires for toddlers to evaluate the social and behavioural characteristics, and can also be taken by parents and caregivers. At the end of each test, which takes approximately 20-30 minutes to complete, the app pinpoints the likelihood of the toddler possessing autistic traits. ASDDetect app has three types of tests based on the toddlers age (12, 18, and 24 months).The app has been able to gain 4.5 ratings, the highest among other considered screening apps (ASD Detect org., 2016). Research carried out by the app developers claims that the screening accuracy of the results generated by ASDetect is about 81% when compared with export screening. Nevertheless, this has not been verified by independent researchers. Currently, there are 33 reviews of this app in which most were positive while some users commented about the comprehensiveness issue since the app only focused on the psychological behaviours of young children. Moreover, some reviews specified that the ASDDetect app should cover a wider audience, especially for children older than 2 years of age, which has so far limited the use of the app among the health community for ASD screening.

**2.6 Indian Scale for Assessment of Autism**

One of the methods used to assess an individuals’ level of autism is the Indian Scale for Assessment of Autism (ISAA) (Ministry of Social Justice & Empowerment: Government of India, 2014; Chakraborty, et al., 2015). An app based on the ISAA with English and Hindi versions, ISAA was developed to help parents, particularly in India, to evaluate their child’s level of autism by answering 40 questions covering different autism areas. Each question has a number of alternatives and the user navigates through a large number of screens to receive their end score and its corresponding autism rate. Any score below 76 shows no autistic traits while any above 153 exemplify severe autistic traits. In- between scores exhibit differing autism levels. Currently, the app has 28 reviews with a 4.4 rating on Google store. No ratings or reviews are given on the ISAA app in the Apple store.

**2.7 Naturalistic Observation Diagnostic Assessment (NODA) App**

NODA is a medical research-based mobile app developed to provide parents with proper guidance on autism traits among children, and thus, the app is not a screening tool like the previous apps (Behaviour Imaging Inc., 2015). NODA uses a custom set of videos combined with the advice of experts to help parents understand the cognitive challenges of their children. To use the app users must register and go through a verification process. They are then able to record, and upload videos of their children experts can provide comments. Unfortunately, these processes (besides the technical skills needed to navigate through NODA) have limited its use among users and the health community. Currently NODA has no reviews or ratings in either the Google or Apple stores. Finally, NODA generates a report for the user so medical experts can use it during the diagnosis process later.

**2.8 Discussion**

Table 1 shows a comparison between the previously discussed ASD mobile screening apps in terms of atypical features such as functionalities, coverage, rating, reviews, and target users among others. Out of all of the autism testing apps considered, ASDetect and ISSA have been able to obtain good ratings with approximately 30+ user reviews. All the considered apps are using questionnaires to detect the autistic traits, and some such as AaB and ASDDetect utilise videos. Apparently, questionnaires are more favourable to users than videos, as the apps that are using videos have gained little to no ratings from the users. According to user reviews, many believe video screening to be more time consuming than taking a questionnaire-based test. In questionnaire tests such as AT, however, the number of questions made the screening process lengthy and users may lose interest in using the app over such time. The ISSA, AT, and ATA apps seem to cover a larger segment of ASD users as they target both adults and children. Only a few apps are available in both Google play and Apple iTunes stores, making them accessible to both iPhone and Android users. The majority of the apps, however, offer their tests only in the English language and thus a larger audience is not able to make use of them. More importantly, no ASD testing apps have been found that cover toddlers, children, adolescents, and adults collectively, making the available apps narrow in their scope of coverage.

**Table 1**: ASD screening Apps in terms of their features

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| APP  Name | DEVELOPER | TARGET | RATING | REVIEWS | APPLE  ITUNES | GOOGLE  STORE | VIDEO  USE | IMAGES  USE | SCREENING | NO. OF  QUESTIONS | LANGUAGE | REFFERENCE |
| AaB | Duke University & Apple Researchers | Parents > 18 years with children < 6 years | x | 7 | √ | x | √ | x | √ | 50 | English | Duke University, 2014 |
| AT | Simon Baron-Cohen | Adults & Children | 3.9 | 247 | √ | √ | × | × | √ | 50 | English  Arabic | Google play store,2017 |
| ATA | Consurgo Medical | Adults & Children | 3.3 | 108 | × | √ | × | × | × | 20 | English | Google play store ,2017 |
| ASD  Detect | La Trobe University | Toddlers- 12, 18 and 24 months | 4.5 | 33 | × | √ | √ | √ | √ | 10 | English | La Trobe University, 2016 |
| NODA | Southwest Autism Research Centre | Children | × | × | √ | √ | √ | √ | √ | na | English | Google play store,2017 |
| ISSA | Ministry of Social Justice & Empowerment | Children & Teenagers | 4.4 | 28 | √ | √ | × | × | √ | 40 | English  Hidi | Ministry of Social Justice & Empowerment: Government of India, 2009 |
| ANDDS | Apple Inc. | Infants - 6, 12, 15, 18, 24 and 36 months | × | × | × | × | × | × | √ | unknown | English | Apple Inc ITunes, 2017 |