GesTEApp: A Pilot Study on an Expert Web-Based System that Integrates Gestural Analytics and a Hybrid Recommendation System to Support the Early Detection of ASD in Children

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Abstract: *Autism Spectrum Disorder* is a neurological condition that affects 1 in 160 children worldwide. To date, this disorder does not yet have a standardized cure, and not being treated early can affect the child's quality of life and their relatives. There are currently different traditional tools for detecting Autism Spectrum Disorder, such as questionnaires and checklists— standardized methods worldwide, such as using M-CHAT-R/F and Q-CHAT. We present GesTEApp as a web-based expert system that integrates gestural analytics and supports Healthcare Professionals in their medical decision-making process on the early detection of this disorder in children. GesTEApp implements a Hybrid Recommendation System with Face Recognition models and Linear Kernel, which capture and analyze children's facial expressions, seeking to support Healthcare Professionals in detecting Autism Spectrum Disorder. We evaluated this tool following a pilot study and reported the findings and results considering Healthcare Professionals' perceptions, basing our analysis on (1-5) Likert Scales and their feedback regarding their experience interacting with GesTEApp. Preliminary, the tool reduced detection times by 36% compared to traditional tools. Also, our preliminary results suggest that GesTEApp is a user-centered web-based application that satisfactorily supports Healthcare Professionals in detecting Autism Spectrum Disorder in children.

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by causing persistent deficiencies in communication and social interaction in various contexts (Lord et al., 2020). It manifests in socio-emotional reciprocity from an abnormal social approach, shared affections, and social interaction. Moreover, impairments in nonverbal communicative behaviors, abnormalities in eye contact and body language, as in comprehension and use of particular gestures, are also manifested (Spitzer et al., 1980).

According to the DSM-V (i.e., Diagnostic and Statistical Manual of Mental Disorders), the symptoms must be present in the first phases of the person's developmental period but may fully manifest until the social demand exceeds the limited capacities (Edition et al., 2013). Although there is no standardized cure for ASD to date, different studies have shown that early detection of the disorder and initiation of treatment in time to maximize the individual's functional independence can improve the quality of life of the person and their relatives (Lai et al., 2014).

Numerous screening tools such as questionnaires and checklists have been implemented worldwide regarding ASD — screening tools such as Q-CHAT (Roman-Urrestarazu et al., 2021), M-CHAT (Dumont-Mathieu and Fein, 2005), M-CHAT R/F (Coelho-Medeiros et al., 2019), among others. These tools have helped to diagnose ASD before two years of age, presumingly. Despite this, the criteria for making this diagnosis in children have yet to be well-established (Goin-Kochel et al., 2006). Generically, the tools commonly used to detect ASD are based on questionnaires made to parents and Healthcare Professionals (HcP). Unfortunately, this shows the lack of resources of technological tools to support the detection of ASD and related disorders.

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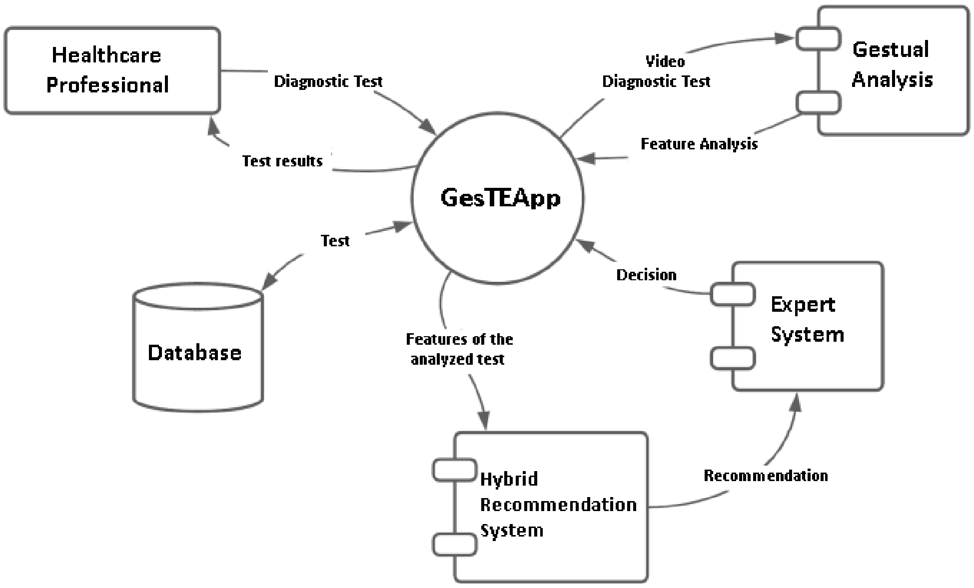

Figure 1: Conceptual design of GesTEApp.

It is estimated that approximately 16% of South America's population under 15 years of age suffer from some developmental disorder. However, the prevalence of this disorder has not yet been established to date (of Health, 2015).

We present GesTEApp as a web-based expert system based on a recommendation system that supports the detection and analysis of behavioral patterns of patients (i.e., children) and finds matches with the most representative of ASD, stipulated by medical literature. Hybrid Recommendation Systems combine different recommendation systems to produce outputs to complement their features and make better conjoint recommendations (Seth and Sharaff, 2022). Therefore, GesTEApp recommends to the user (i.e., HcP) a customizable report to support their medical decision-making processes on carrying out specialized or deepened tests, as to consider the referral to specialists to obtain an official diagnosis regarding ASD more effective, efficient, and objectively — through the integration and implementation of a hybrid recommendation system.

We intend GesTEApp to be implemented in the first stage of the medical process— in the mandatory pediatric controls. Hence, we look forward to GesTEApp supporting the detection of the first signs of the disorder from the first medical approach and avoiding long waiting times given by the traditional screening tools for the first screening evaluation— the waiting times depend on the region or country where the ASD test is held (Lord et al., 2020).

Our work contributes to Healthcare Information Systems and Artificial Intelligence literature— the solution implicates the relation between a hybrid recommendation system and gestural analysis through artificial vision. As a result, GesTEApp intends to reduce ASD detection times compared to the ordinary. Additionally, we look forward to the web-based application being accurate with its results concerning the recommendation made following the evaluation standards of Machine Learning models (i.e., accuracy >= 75%), implying a low error rate and fewer false positive cases. Also, with this healthcare-based solution, we intended to increase the end user's satisfaction (i.e., HcP) regarding the support to ASD detection or related medical decision-making processes. Thus, we ask the following questions: How can the medical procedure of detection of ASD be quantified and supported by artificial vision? How can a technological tool, through an expert system based on a recommendation system that implements gestural analysis, support HcPs in the early detection of ASD, reduces procedural times, and increase detection accuracy?

We evaluated this tool following a pilot study and reported the preliminary findings and results considering HcPs' perceptions, basing our analysis on (1-5) Likert Scales (Joshi et al., 2015) regarding their experience interacting with GesTEApp. This approach uses e-health-based (Eysenbach et al., 2001), artificial intelligence, emotional intelligence (Prentice et al., 2020),seeking to support medical decision-making processes for HcP with the early detection of ASD.

2 GesTEApp: DESCRIPTION

We present GesTEApp as a web-based approach that integrates a hybrid recommendation system that, with constant automated learning, supports the detection process and analysis of behavioral patterns of patients (i.e., children aged 2 to 5 years), and finds matches with the most representative features of ASD determined and analyzed to date (Talero-Gutiérrez et al., 2012). Similarly, with the hybrid recommendation system (Çano and Morisio, 2017), the application recommends to the end-user (i.e., HcP) if it is considered necessary to carry out specialized tests and referral to specialists to obtain an official and structured diagnosis or to support a related diagnostic process— a general conceptual design of GesTEApp is represented in Figure 1.

We intended to implement GesTEApp in the first stage of the medical process— in the mandatory pediatric controls. This is because we preliminary looked forward to detecting the first signs of the disorder (i.e., ASD) from the first medical approach and avoid encountering long waiting times for a first detection evaluation.

The detection through behaviors of spectrums, such as ASD, lets us reflect on technological tools supported by visual (i.e., the recognition of what is perceived) and less methodical procedures, providing a less traditional and subjective observation by treating physicians towards movements and actions of the patient. Artificial vision (i.e., computer vision) models have proven to be effective and helpful in identifying attention and focus behavior patterns and capturing reactions in people with ASD when faced with visual stimuli.

With GesTEApp, we intended to present the results obtained in ASD tests through real-time images and screenshots of the patient's reaction when the web-based tool captured the emotion in time intervals. We meant to visually communicate to the HcP the patient's response and allow medical contrasts concerning the expected emotion in a particular time interval. Also, given the automated and customized recommendation of possible detection of ASD in children, GesTEApp permits the recommendation's validation and supports particular medical decision-making processes. Therefore, the evaluation of the proposed technological solution depended principally on: **(1)** *time* to reduce the ASD detection times compared to the ordinary medical detection process, and **(2)** the accuracy of the hybrid recommendation model.

We focused GesTEApp on HcP, which allows them to apply standardized ASD tests on the web-based platform and support their medical analysis on children (i.e., patients). The solution consists of five modules. **(1)** *Test creation module*: Allows the creation of a new test for a patient. **(2)** *Patient creation module*: Allows the creation of new patients in the system. **(3)** *Patient consultation module*: Allows the consultation and modification of a patient's information previously created in the system. **(4)** *Test detail module*: Allows observing the evaluated test results, the patient's information, and the information by time interval. Also, it lets the HcP perform the test qualification. **(5)** *Test rating module*: The HcP can enter a rating for a test performed through numerical and open-ended feedback (see Figure 2).

The hybrid recommendation system consisted of the conjunction of **(1)** a *Content-based Recommendation System* and **(2)** a *Collaborative Filtering Recommendation System*. The Content-based Recommender used a syntactic analysis of the information in the database related to the test and the user, such as the results of dominant emotion, response rate range, and patient age and gender. On the other hand, the Collaborative Filtering Recommender considered the rating given to the tests, fed by the sentiment— extracted from a sentiment analysis (Zunic et al., 2020) applied to the observations generated by the HcP. We evaluated the sentiment analysis on three levels of analysis: **(1)** Negative, **(2)** Neutral, and **(3)** Positive. The resulting hybrid recommendation system is constantly consulted through web services (See Figure 3).

3 DATA ACQUISITION

The participants who contributed to the experimentation had roles of HcP and children aged 2 to 5 years. Each HcP performed specific tasks in the web-based solution in this pilot study. Six (N=6) HcPs participated in the experimentation phase interacting with the tool and requesting feedback. In addition, four (N=4) clinically healthy children between 2 and 5 years participated in the data acquisition and observed behavior against GesTEApp.

The HcPs completed a questionnaire regarding the web-based application and how much they recommended GesTEApp. We evaluated this approach following pre-post experimentation. We sought to answer how the platform supported and complemented early detection of ASD in children through gestural analysis and customization through a hybrid recommendation system. Hence, we designed a questionnaire to obtain results on the Perception of Usability, User Experience (UX), and feedback before and when interacting with the system. We based the questionnaire on the SUMI-type questionnaires (i.e., Software

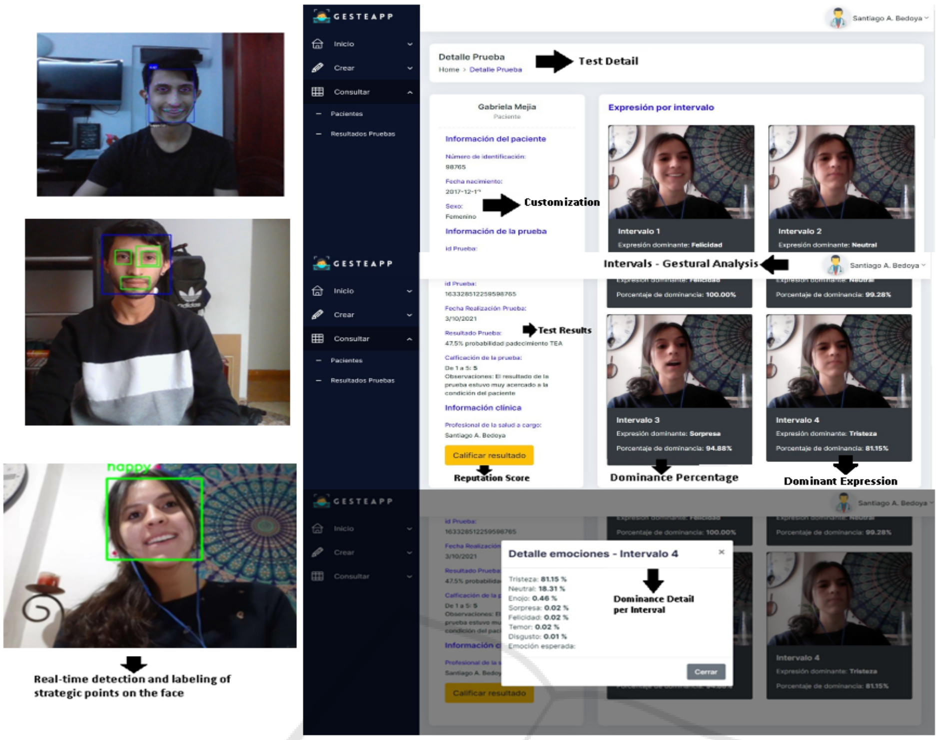

Figure 2: Features/Functionalities of GesTEApp (customization features).

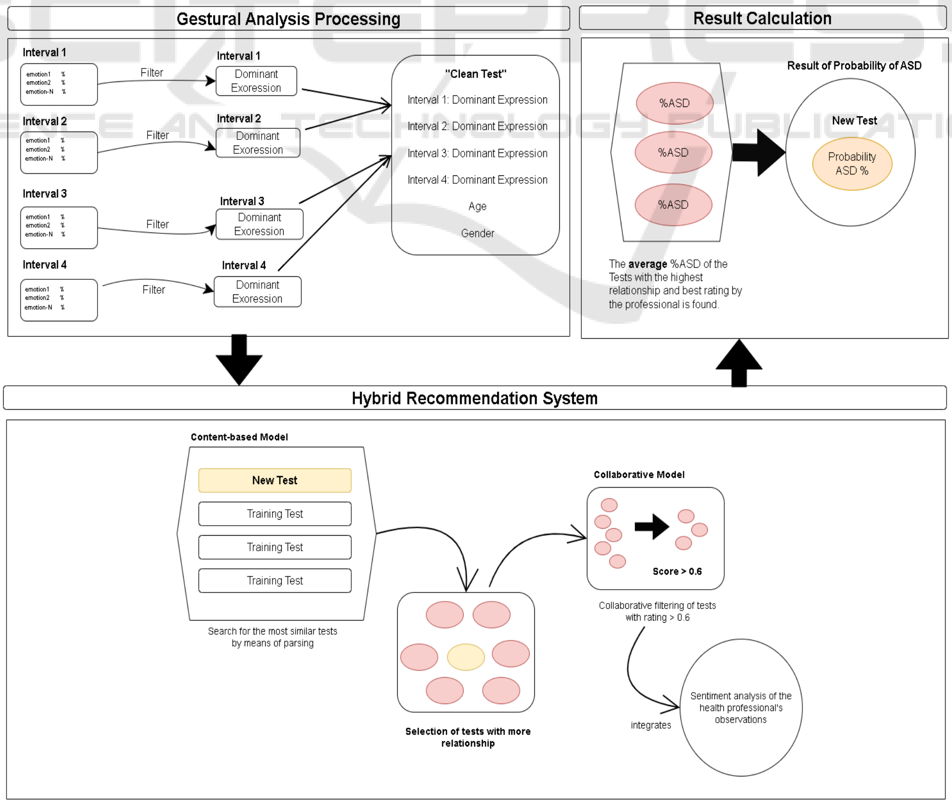

Figure 3: Features/Functionalities of GesTEApp (preliminary customization features).

Usability Measurement Inventory), which allow the evaluation of a set of software from the point of view of the end user (Mansor et al., 2012). The questionnaire considered Open-Ended, Y/N, and (0-5) Likert-scale (Joshi et al., 2015) responses (See Table 1).

4 EXPERIMENTAL APPROACH

We implemented GesTEApp in a real-world setting, and to understand the sociocultural transition that occurred in a particular context, we examined the (1) Habits, (2) Beliefs, (3) Artifacts, and (4) Means of the actors involved (i.e., HcP and Patients). These components for analysis are part of the Biopsychosocial and Cultural Systemic Model (BPSCM) introduced by Universidad El Bosque, Colombia (Cruz and Buitrago, 2017). This model helped us comprehend the situation, and we looked forward to enhancing complexity in this field. Furthermore, this model could describe how its components may systemically change if the participants engage with the web-based tool.

Therefore, we evaluated GesTEApp carrying out a pilot study on five patients (N=5) and six HcP (N=6). We assessed the interaction of the web-based tool with a sample of 5 individuals from the target population (i.e., children between 2 and 5 years old). We looked forward to observing and evaluating its applicability, reception, and behavior against the solution.

Following the Technology Transfer Cycle (TTC) (Gorschek et al., 2006), we followed a case study strategy. HcP principally validated GesTEApp to obtain feedback on the web-based tool. In addition, this strategy made it possible to validate both qualitative and quantitative variables, allowing the system to be observed from a broader vision, evaluating and understanding the performance of GesTEApp from the variables "time" and "accuracy of detection" -quantitative- and "support to the health" -qualitative.

We designed and asked HcPs to respond to a questionnaire after interacting with GesTEApp to obtain their feedback and perception of usability, user experience, and times involved. Moreover, we applied the observation method (Ciesielska et al., 2018), which contributed us to evaluate the perception of the interaction of the actors (i.e., HcP and patients) with GesTEApp without intervention or external help, allowing us to support the validation of the user experience, usability, preliminary detection times and its applicability in particular contexts.

We validated the questionnaire using an inter-agreement measure (Jolivald et al., 2022). We considered the calculation of the Intra-class Correlation Coefficient (ICC) with three (N=3) raters for the 14-item questionnaire (see Table 1). We followed the standardized process for the calculation: **(1)** Each rater evaluated all the questions following a 5-point Likert-scale (Joshi et al., 2015); **(2)** calculated the between-group sum of squares across all raters; **(3)** calculate the within-group sum of squares across all items and item-based ratings; and **(4)** considered the formula for *ICC(2,3)* to calculate the ICC. We obtained an ICC of 0.83 (i.e., 83% of variance), which means that the questions posed in the questionnaire were considered consistent and reliable— an ICC of 0.75 or higher indicates good to excellent agreement.

Likewise, we proposed the following general validation steps: **(1)** Find the environment where the case study would be carried out (e.g., foundation, clinic, among others), **(2)** Establish interviews with expert and non-expert HcP in the area, who evaluate the operation and coherence of the technological tool from their medical perspective through a questionnaire. In addition, make an observation method towards the use of the tool by the HcP, allowing us to evaluate the HcP's perception of usability and user experience (UX) of the web-based tool, and **(3)** Execution of a Test Plan for the validation phase of GesTEApp.

5 FINDINGS AND RESULTS

The ability of GesTEApp to be understood, used, learned, and visibly attractive to the HcP was evaluated. As a result, 100% of the HcP agreed with the ease of use of the tool. On the other hand, 60% of HcP positively considered the probability of rapid learning to use the tool by HcP.

Regarding the user experience validation towards the HcP's perception of GesTEApp, we obtained that 80% of the HcP considered that the solution provided easy navigation. Also, 80% believed the information on the test result provided by the tool was sufficient. Moreover, 80% would be willing to implement this tool frequently, and 50% of HcPs considered its graphic interface very pleasant.

We could obtain the following preliminary observations from the validation with the child population. First, some children responded more expressively than others to the video. We could observe that this depended on their age and the environment in which the test was applied. This suggests the need to locate the child (i.e., patient) in controlled environments— for example, the camera should focus directly on the child's face instead of the complete body. Also, it is necessary to eliminate any distractions that could interfere with the application of the test. More-

Table 1: Questionnaire regarding the pre-post experience of HcPs interacting with GesTEApp.

Question	Type of Question: MC(1), OE(2), LS(3) or YN(4)	Moment of Application: B(5) or A(6)
Q1: Provide your age range.	MC	B
Q2: Which is your current job title?	OE	B
Q3: Which is your professional specialty in health?	OE	B
Q4: Indicate if you have worked on patients with ASD.	YN	B
Q5: The Graphical User Interface (GUI) of GesTEApp is easy to use.	LS	A
Q6: Indicate how you consider the invested time of the ASD test to be.	LS	A
Q7: GesTEApp could be implemented within the periodic checkups for pediatric development control.	LS	A
Q8: HcPs would quickly learn to use GesTEApp.	LS	A
Q9: How easily do you consider navigation through the different components of GesTEApp?	LS	A
Q10: Indicate how you consider to be the supplied information of the test result of GesTEApp.	LS	A
Q11: How visually pleasing is the graphical interface of GesTEApp?	LS	A
Q12: How willing would you feel to use this tool frequently?	LS	A
Q13: How useful do you consider GesTEApp in supporting the early detection of Autism Spectrum Disorder in children from 2 to 5 years of age?	LS	A
Q14: General feedback on the tool (Aspects to improve/opinions/suggestions)	OE	A

Notes: (1)MC: Multiple Choice, (2)OE: Open-Ended Question, (3)LS: [0-5] Likert Scale,(4): YN:Y/N Questions, (5)B: Before using GesTEApp, (6)A: After using GesTEApp

over, we also observed that most children showed interest in the emotion-inducing video, which is considered a significant achievement for this pilot study— the emotion-inducing video was included in the case-based experimentation approach.

On the other hand, we can also assert that there is no instance of overfitting (Ying, 2019) or underfitting (Sehra et al., 2021) if we acquire an F1-Score of between 70% and 85% (i.e., we achieved 71%). Also, the specificity resulted in 100%— the specificity is understood as the negative cases that the algorithm correctly classified.

Regarding the time it takes to carry out the entire flow of the process with GesTEApp by the HcP, from the beginning of the session until the result is obtained (i.e., recommendation), we conducted ten test scenarios (N=10) to evaluate the duration of the whole test process. As a result, GesTEApp reached an average time of 8.4 minutes, including taking the test and generating the result, with a standard deviation of 1.57, demonstrating a low dispersion of the data and stability concerning the execution times of the test— representing a 36% reduction compared to traditional tools.

Although the symptoms and behavior of ASD are naturally varied and heterogeneous, which leads to considering it a *spectrum* (Masi et al., 2017), it is possible to take into account some patterns that can be used to support detection procedures through automated recommendations. This is evidenced in GesTEApp, where patterns of facial expressions were considered to generate personalized recommendations regarding ASD in children.

Moreover, from the feedback and perceptions of the HcPs, the recommendations that GesTEApp provides support medical decision-making processes, and promote a deepened medical analysis in their procedures to achieve early detection of ASD in children, as intended with the solution proposed and analyzed in this paper. Also, we found that it is possible to support an early detection medical procedure on ASD from its first manifestations and by implementing technological tools such as GesTEApp.

6 DISCUSSION

From the preliminary results of this pilot study, we can claim that GesTEApp could positively generate a probability of suffering from ASD in children— quantitative support. This helps the HcP in decision-making, capturing and analyzing primary manifestations of ASD based on difficulties or ability to express emotions, giving them extra support for much more objective medical decision-making processes. Therefore, GesTEApp is an expert system with case-based reasoning because it proposes a possible probability of the suffering of ASD in children from the comparison with similar tests extracted from a case base.

According to the literature, children with ASD tend to have difficulty processing the basic emotions of disgust, anger, and surprise (Smith et al., 2010). On the other hand, children with ASD have some difficulties in recognizing and expressing the emotion of surprise due to two main factors: First, since the expression of surprise involves the decoding of the expression of the eyes and mouth, unlike the emotion of "happiness" and "sadness" that can be decoded simply through the mouth. The second reason is justified by how complex the emotion of "surprise" can become because this expression can usually mix more than one emotion, thus making it difficult for children with ASD to understand and replicate it.

Therefore, we opted to calculate and analyze a percentage probability of suffering from ASD within a detection traffic light (Omachi and Omachi, 2009). We considered green between 0% to 33% probability of detection of ASD, yellow (+) between 34% to 50%, yellow (-) between 51% to 66%, and red between 67% to 100%.

GesTEApp successfully offers a friendly and user-centered web-based solution to support HcPs in the early detection of ASD in children, according to the preliminary results and comments obtained of this pilot study. Additionally, we discovered that the participants' feedback on their web-based platform experience was favorable and very helpful to what we intended with the solution, which let us use their suggestions to improve the tool for subsequent iterations.

The expert system integrated two main components: **(1)** an inference engine and **(2)** a case base. The case base contained information on the previously resolved problems— it included the tests that have already been carried out, analyzed, and evaluated by the system with feedback from the HcP. On the other hand, the inference engine (Naykhanova and Naykhanova, 2018) compared the inserted problem (i.e., the test to be evaluated) with the problems stored and solved in the case base to obtain a result that meets the highest degree of similarity.

All HcP (i.e., participants of the pilot study) who interacted with GesTEApp agreed regarding the tool's ease of use. Furthermore, 60% of them positively consider the possibility of rapid curve learning using the tool.

Additionally, regarding user experience validation of the web-based tool, we evaluated the HcP's perception and response to GesTEApp. In the first place, 80% of HcPs considered navigation through the application modules easy and the information from the test result provided by the tool sufficient and would be willing to implement this tool frequently in their medical procedures. According to the Harris Poll conducted in collaboration with Stanford University, 55% of HcP are willing to experiment with and adopt new technologies provided by other HcPs, who have previously utilized and approved them (Wuerdeman et al., 2005). Therefore, 80% of the participants considered the tool's graphical interface (GUI) friendly, despite 20% of the participants who considered it not very pleasant. Moreover, compared to GesTEApp, traditional tools take an average of 15 minutes to apply a detection test, in addition to the duration of evaluation of the responses and analysis by the HcP to obtain a final result.

Moreover, we can also claim that it is possible to support HcPs in detecting ASD (i.e., Autism Spectrum Disorder) through an expert system based on a hybrid recommendation system that implements gestural analytics models that manage to capture and analyze the facial expressions of children. This tool contributes to understanding behaviors and emotions in the diverse diagnoses used by HcP to detect this spectrum disorder. Therefore, we can preliminary state with this pilot study that a tool such as GesTEApp supports this idea. Nevertheless, further research on the web-based tool proposed to support HcPs for early detection processes of ASD in children will be carried out to substantiate and fulfill all assertions discussed in this document.

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