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PAPER

Analysis of the Recognition of Facial Movements of App Designed for Rehabilitation of People with Facial Paralysis

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ABSTRACT

Peripheral facial paralysis (PFP) causes deficits in muscle and sensory functions of the face due to damage to the facial nerve. In this study, we evaluated the effectiveness of the "Fisiobem" app in rehabilitating patients with PFP through facial mimicry exercises. The app uses the device's camera to identify the user and measure the range of motion during the exercises, applying the ARKit framework to quantify the intensity of the movements. We conducted a usability study with 34 participants unaffected by PFP, performing mimics with different amplitudes. Results show that glasses did not affect recognition accuracy in exercises such as raising eyebrows, frowning, and closing the eyes tightly. As for wrinkling the nose exercise, glasses impacted higher intensities. As for the beard or mustache, lower lip protrusion, compressing the lips, smiling, showing teeth and blowing out filling cheeks were not affected. However, when smiling with lips together, beard and mustache influenced intensities above 75%. It is important to highlight that this study has limitations, such as the sample size and lack of consideration for ethnic diversity among participants. Future research with larger and more diverse samples is needed to validate and generalize these findings and explore the nuances of interactions between facial features and facial recognition algorithms. Despite these limitations, the approach facilitated by the "Fisiobem" application offers significant benefits, especially for patients with PFP who face challenges in accessing specialized therapists. It allows patients to complement their treatment by performing guided facial mimicry exercises at home. The application helps individuals accurately perform the exercises and effectively track the progress of their rehabilitation.

KEYWORDS

augmented reality, peripheral facial paralysis (PFP), motor rehabilitation

1 INTRODUCTION

Peripheral facial paralysis (PFP) is a pathology that affects the facial nerve, generating a neuropathic lesion. The most predominant type of paralysis is Bell's palsy [1]. Patients with PFP have impaired muscle and sensory function on one side

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of the face. The sequelae of PFP include incomplete ocular closure, oral dysfunction and asymmetry, dysphonia, muscle contractures, impairment of facial joint movements, and pain [2]. In addition to the sequelae mentioned above, due to the inability to fully express emotions, PFP generates deleterious effects on patients that significantly compromise their aesthetics, social life, and communication [3].

The type of PFP treatment depends on where the facial nerve injury occurred and the time since the first symptoms appeared. Still, it can generally be surgical, pharmacological, and physiotherapeutic [1]. Physiotherapy offers the possibility of carrying out home programs that offer the patient daily muscle exercises as a model of individualized and continuous training [2]. At this point, technological resources can act as support, helping both healthcare professionals and recovering patients.

In the "Play Store" and "Apple Store" application stores, you can find several applications developed to assist in the treatment of PFP, such as "Face2face," "Face it!," "The eFACE," "MEPP," and "Facial Palsy Therapy and Rehab." These applications aim to describe and inform about PFP, clarify doubts about the disease, and instruct about physical exercises that can be performed to assist in the recovery of patients.

The literature shows efforts to create technological solutions to support the rehabilitation of people affected by PFP. Noteworthy is the work conducted by [4], which improved techniques for locating facial landmarks and calculating facial measurements. [5] developed a tool capable of creating 3D facial models from 2D images (photos) of the patient. The SORIE tool, created by [6], is a serious game for children that, using the Kinect sensor (motion sensor), detects the movement of facial muscles. [7] used electromyography (EMG) sensors integrated into a pair of virtual reality glasses to detect and monitor the activation of the facial muscles responsible for expressions. Despite all these advances, such technologies are not yet fully accessible, are mostly time-consuming to set up, require expensive and complicated hardware, and can be difficult to implement in clinical practice. Furthermore, they are not available for home use, freely and independently, by the patient.

The improvement of mobile technologies, such as smartphones and tablets, can promote this independence and satisfaction, providing a new form of physiotherapy proposed for home use with remote monitoring by physiotherapists [8, 9, 10]. For PFP, users can perform facial rehabilitation exercises at the most convenient time using a free and easy-to-use app [11, 12]. This technology is especially helpful for people with a busy schedule or who cannot easily travel to a rehabilitation center. Besides, when using an intuitive and free application, the user does not need to bear the costs often associated with in-person therapies or purchasing specific devices. All of this makes facial rehabilitation more financially accessible. In addition to rehabilitation, [13] explored methods for expression recognition to categorize photographs of human faces in different emotional states, such as happiness, fear, neutrality, surprise, sadness, etc. [14] proposed a design for smart home multi-factor authentication using facial recognition and a one-time password sent to smartphones for a home security system.

In this sense, a mobile application was developed called Fisiobem [15], which aims to help individuals affected by PFP perform a facial mimicry exercise routine. The app works as follows: the user holds the cell phone or tablet with the device's front camera; next, select an exercise, for example, raising the eyebrows; then the mobile device's front video camera is enabled to start recognizing the user's face; at this point, the user must reproduce the exercise illustrated in the video (facial mimicry) for a period (in seconds) previously determined.

Recognition of phase movements is achieved through the Apple ARKit framework (iOS) [16] used to undertake this intensity control, which allows the user's face to be mapped using non-physical markers (anchors) positioned on the individual's face using augmented reality. The range values returned by the framework can vary between 0.0 and 1.0 (mapped in the app as 0% to 100%), where 0.0 (0%) represents the neutral condition, that is, face at rest, and 1.0 (100%) represents the maximum range of motion (ROM) of the face movement.

We noticed that the detection of ROM at 100% varies from exercise to exercise and from person to person, meaning that for some exercises (e.g., closing the eyes tightly), the maximum motion range threshold works well at 100%, while, for other exercises (e.g., lower lip protrusion), there are many recognition failures in the execution of facial mimicry. It is, therefore, necessary to check the maximum degree of ROM for each exercise, regardless of the user's features (glasses, beard, piercing, among others), thus making the tool more accurate and avoiding frustration for the users in using the app.

This research conducted a study with 34 typical people aged 19 to 53 (without reports of PFP) who tested the app by performing facial mimicry in 55%, 65%, 75%, and 85% ROM. Questionnaires were used to measure the success or failure of tasks (considering points 0 – failure; 1 – half-to create a 3D mesh with information about the size, shape, topology, and facial expression of the user's face, and 2 – success); a satisfaction questionnaire was used with reports of improvements, observations, and general considerations. The recommendations were passed on to the Fisiobem developers to adjust the app and launch a second version.

Our main contribution in this research is to have designed a free application for the rehabilitation of people with facial paralysis that can be used from the comfort of home, as it offers a series of benefits. Firstly, Fisiobem allows individuals with facial paralysis to have access to exercises and guidance specific to their case, helping them to recover facial movements and improve non-verbal communication. Furthermore, Fisiobem offers convenience by allowing users to perform exercises at their own time and pace without having to travel to a clinic or hospital. This not only saves time and money but also facilitates adherence to treatment, increasing the chances of recovery. Fisiobem can also be a valuable resource for people who live in remote areas or who have difficulty accessing specialized clinical services. In summary, this study became essential in the final stage of Fisiobem development, as it is an app with potential commercial use to support more individualized and continuous facial physiotherapy training.

1.1 Fisiobem

Fisiobem [15] is a mobile app developed for rehabilitating patients with PFP (see Figure 1). The app was developed for iOS platforms using computer vision—detection and recognition of facial movements—and augmented reality (Apple ARKit [16])—to create a 3D mesh with information about the size, shape, topology, and facial expression of the user's face. Among the various options for detecting specific facial features and movements offered by the ARKit library, functions for the recognition and detection of facial movements were implemented for the development of FisioBem. These exercises focus on the dynamics of the muscles involved in the rehabilitation of peripheral facial paralysis through facial mimicry, also known as kinesiotherapy [17].

In this sense, the app enables the user to select nine facial mimicry exercises (see Figure 1a): (1) raising the eyebrows; (2) frowning; (3) wrinkling the nose; (4) closing the eyes tightly; (5) blowing out, filling the cheeks; (6) smiling, showing teeth; (7) smiling with lips together; (8) compressing the lips; (9) lower lip protrusion. The following settings can be made in the app for each exercise (see Figure 1b):

- Repetitions: the number of times the patient should perform the facial mimicry.
- Intensity: the patient's ROM during facial mimicry (0% to 100%).
- Time (seconds): length of time the patient must maintain the facial mimicry.

Figure 1c shows an example of the user performing the "raising the eyebrows" exercise. On this screen, there is some information for the user: counting down time (e.g., 2s), number of repetitions (e.g., 2/4), video demonstrating mimic.

Fig. 1. Features of the Fisiobem app: (a) proposed exercises; (b) configuration; (c) execution

Note: [15].

The detection and verification of facial mimicry ROMs is provided by the ARKit library, which is designed to assist developers in creating solutions using augmented reality [16]. The calculation uses a face-tracking algorithm, which uses input data such as the camera position, the ambient light, and the user's movements to determine face position and orientation. Thus, it offers the option of generating markers (or anchors) that map the user's face and allow real-time detection of facial expressions such as smiling, frowning, and raising the eyebrows, among others. The ARKit library allows you to map the Cartesian position of these markers and determine their displacement in a region of the face during the motion execution. The calculated displacement of the markers determines the intensity of the performed movement.

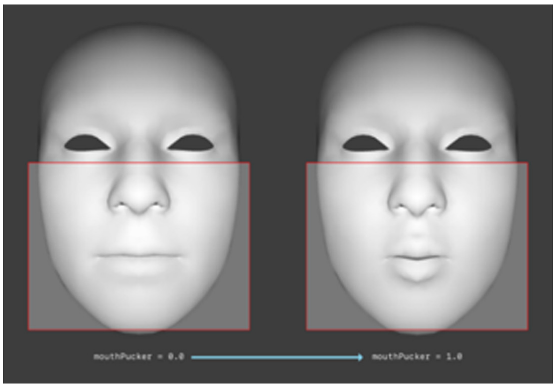

Fig. 2. Assessment of lip protrusion performed by the ARKit library

Note: [15].

Figure 2 presents an image of the lip protrusion exercise provided by the ARKit library documentation. In this image, it is possible to observe a face performing lip protrusion mimicry, where the mouthPucker variable equal to 0.0 represents the condition in which the face markers are at rest, and mouthPucker equal to 1.0 represents the condition in which the face markers are active at their maximum level.

In addition to assisting in the execution of facial mimicry exercises, Fisiobem allows you to classify the patient's progress during treatment using the House & Brackmann scale (Fonseca, 2015). This functionality allows you to create a chronological record of the patient, with the assessment date, the PFP level, and photos taken during the evaluation process. However, this aspect is not covered in this study.

2 MATERIALS AND METHODS

The flowchart illustrated in Figure 3 shows the research steps. The execution of each of these steps is further detailed in the subsequent sections.

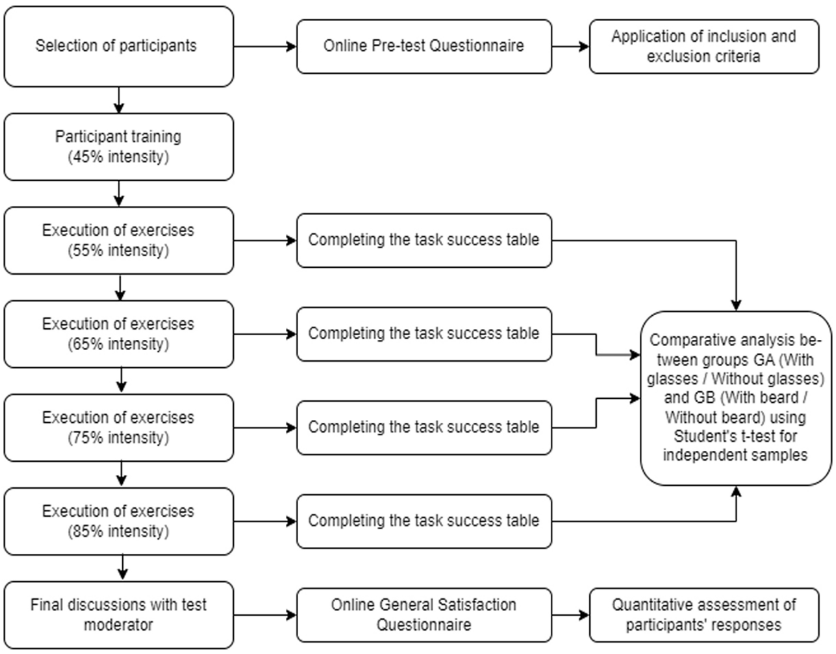

Fig. 3. Research execution flowchart

2.1 Objective

This study aimed to verify the accuracy of the FisioBem app in recognizing facial expressions at different ROMs (55%, 65%, 75%, and 85%). As well as assessing whether using different accessories or features such as glasses, piercings, botox, beards, and mustaches would influence facial expression recognition during the execution of facial mimicry exercises.

The following research questions guided this study:

Question 1: Is the success rate of the exercises, in the respective ranges of motion, the same for all groups of participants?

Question 2: In which range(s) of movement does the exercise(s) fail the most for each group of participants?

2.2 Participants

The Research Ethics Committee approved the study (CAAE: 44150821.4.0000.0084). Thirty-four people of age between 19 and 53 of both sexes participated in the study without suffering from PFP. Participants wearing glasses, beards, piercings, and botox were recruited to identify interference in the measurement results. The inclusion criteria were (1) age over 18 and (2) no PFP complications throughout life. Exclusion criteria: having a visual impairment that hinders the use of the app; having motor limitations in the upper limbs that prevent them from holding the mobile device; having had previous experience with the app so as not to influence the results with preconceived information.

Participants were recruited online via the researchers' social networks. The interested participants answered a pre-test form online, providing their personal data and facial features. Appointments were made via the WhatsApp tool.

2.3 Tasks

Each participant performed four rounds of exercises, each consisting of nine facial expression tasks (refer to Table 1), totaling 36 tasks (refer to Table 2). Each round was set at a different ROM, starting at 55% (first round), followed by 65% (second round), then 75% (third round), and 85% (fourth round).

Table 1. User tasks

Task 1	Raising the eyebrows
Task 2	Lower lip protrusion
Task 3	Wrinkling the nose
Task 4	Frowning
Task 5	Closing the eyes tightly
Task 6	Compressing the lips
Task 7	Smiling showing teeth
Task 8	Smiling with lips together
Task 9	Blowing out filling the cheeks

Table 2. Exercise battery

1st round (55%)	Tasks 1 to 9
2nd round (65%)	Tasks 1 to 9
3rd round (75%)	Tasks 1 to 9
4th round (85%)	Tasks 1 to 9
TOTAL	36 tasks

The criteria for defining ROM were based on feedback from project stakeholders (physiotherapists, patients, engineers, computer scientists, programmers, and students), considering the functional tests carried out during the app's development. It was observed that, at 75% amplitude, movement detection errors occurred for some exercises, forcing participants to perform very intense facial expressions that were often not detected by the application.

Each exercise was performed with a time setting of five seconds. The user had to maintain the facial mimicry for five seconds.

For each task, the observer assigned a score to identify success or failure: (0) when the app did not detect the facial expression; (1) when the app detected but stopped detecting the facial expression before five seconds; (2) when the app detected the facial expression during the five seconds.

The order of execution of the exercises was organized into three different configurations to avoid data bias (following the order presented in Table 1): the first starting with Task 1, "raising the eyebrows," and continuing until Task 9; the second starting with Task 4, "frowning," and continuing until Task 3; the third starting with Task 7, "Smiling showing teeth," and continuing until Task 6. Each configuration was executed in the sequence in which the participants arrived to perform the test.

2.4 Data collection instruments

Three data collection instruments were used:

1. Online Pre-test Questionnaire (selection of participants): Name; Age; E-mail; Gender; Physical features: wears prescription glasses; wears a nose piercing; wears an eyebrow piercing; wears hair bangs; has a facial tattoo; wears a beard and/or mustache; has scars across the face; if he has ever had facial paralysis/when.
2. Online General Satisfaction Questionnaire (after using the app): a self-authored questionnaire with the following questions: Was the app functional? (1-Not functional to 5-Totally functional); Have you become tired? (1-Exhausted to 5-Well-disposed); most of the time, you felt Tired, Angry, Bored, Pleased, Relaxed, Satisfied, Discouraged, Insecure, Surprised, or Intrigued; Would you recommend the software to someone (1-Totally disagree to 5-Totally agree); Would you like to leave a comment about the experience?
3. Task Success/Failure Form: for each participant, the moderator recorded the degree of success for each of the tasks and inserted comments when necessary.

2.5 Materials and equipment

In this experiment, the following were used:

- iPad Pro model iOS tablet with the Fisiobem App installed
- Questionnaire to collect task success data
- Google Forms questionnaire (overall satisfaction)
- Test Script for the test moderator
- Free and Informed Consent Form (FICT)

2.6 Procedures

An invitation to participate in the survey was e-mailed to students and staff at a private higher education institution with a link to sign up. Those enrolled were sent the pre-test questionnaire to complete beforehand. Of the 41 registered participants, 34 were recruited based on the inclusion and exclusion criteria.

The tests were conducted on two consecutive days in the same environment, always with the same intensity of lighting and equipment. A pilot study was conducted with a volunteer to validate the test protocol for adequacy of time, failures in procedures, and/or data collection instruments. Each test lasted an average of 25 minutes and was performed individually at the scheduled time.

The same moderator and observer applied to all tests. The moderator conducted the test by prompting the completion of each task and collecting the success or failure results of those tasks. The observer took notes to observe all actions performed by the participant and describe any difficulties identified.

An intermediary welcomed participants to read the FICF and answer any doubts; then, he took the participants to the testing room. After the test, he led the participants to a room with a notebook so they could complete the overall satisfaction questionnaire. He thanked them for their participation, ensuring they had support before and after the usability test.

The experiment began with a warm-up round with all exercises at 45% ROM, lasting five seconds for each task. Next, one of the task configurations (1, 2 or 3) was executed, starting at 55%, then at 65%, at 75% and, finally, at 85%.

After completing the tests, the results were compiled into a unifying table with each participant's responses for data analysis. The arithmetic mean was generated among 0, 1 and 2 for each range item. Values close to zero indicate task failures, and values close to 2 indicate task success.

2.7 Data analysis

For analysis purposes, the mimics were classified into two groups: A and B. Group A (GA) mimics refer to the analysis of exercises performed in the upper and middle portions of the face (eye and nose area) and were analyzed considering the sample of people wearing glasses (Glasses) and people without glasses (No Glasses).

The upper and middle part of the face (eye and nose area):

– Raising the eyebrows
– Frowning
– Closing the eyes tightly
– Wrinkling the nose

Group B (GB) mimics refer to the analysis of exercises performed in the lower and middle part of the face (mouth region) and were analyzed considering the sample of people with beard and/or mustache (Beard) and people without beard and/or mustache (No Beard).

The lower and middle portion of the face (mouth and nose area):

– Lower lip protrusion
– Compressing the lips
– Smiling showing teeth
– Smiling with lips together
– Blowing out filling the cheeks

To assess the accuracy of the Fisiobem app in facial expression recognition, the percentage of failures during the detection and execution of proposed exercises was evaluated. Additionally, the mean and standard deviation were calculated based on the values obtained from assessing the success rate of the activity. The use of mean and standard deviation values extracted from the assessment allowed for the evaluation of data homogeneity (degree of dispersion) within the sample, as well as for conducting a comparative analysis between groups GA (with or without glasses) and GB (with or without beard) using student's t-test for independent samples. The aim was to determine whether there are significant differences between the groups in intensity, mean, percentage of failures and standard deviation, considering a significance level of 95%.

3 RESULTS

Table 3 shows the distribution of participants by group (N). Exercises referring to the upper and middle portion of the face were analyzed based on GA data (with or without glasses); exercises referring to the lower and middle portion were analyzed based on GB data (with or without beard).

Table 3. Classification of facial mimicry by group

Raising the eyebrows Frowning Closing the eyes tightly Wrinkling the nose	GA Glass (N = 17)
	GA No-Glass (N = 17)
Lower lip protrusion Compressing the lips Smiling showing teeth Smiling with lips together Blowing out filling the cheeks	GB Beard (N = 13)
	GB No-Beard (N = 21)

The mean task success (success = 2, 1 or 0) and standard deviation were calculated for all groups, were: (0) when the app did not detect the facial expression; (1) when the app detected but stopped detecting the facial expression before five seconds; (2) when the app detected the facial expression during the five seconds.

The percentage of failures considered the number of participants in the sample who could not perform the exercise (success = 0). The Student's t-test was applied to verify that the accessories used by the participant do not influence facial recognition.

3.1 Assessment of the upper and middle portion of the face

In tests on the upper and middle portions of the face, the influence of wearing glasses on the software's accuracy in recognizing facial mimicry movements performed by the user was evaluated at intensities of 55%, 65%, 75%, and 85%.

It is noted that for the exercises "1-raising the eyebrows" (refer to Table 4), "2 – frowning" (refer to Table 5), and "3 – closing the eyes tightly" (refer to Table 6), there was no evidence that the use of glasses may influence facial recognition in these exercises ($p >= 0.05$). The tables show that both groups' success and failure rates are similar. It is also noted that the higher the intensities, the higher the failure rate in both groups.

Table 4. Raising the eyebrows

Intensity	GA	Mean	% Failures	SD	P
55%	No glasses	1.471	17.6%	0.800	1,000
	Glasses	1.471	11.7%	0.717	
65%	No glasses	1.294	23.5%	0.849	1,000
	Glasses	1.294	23.5%	0.849	
75%	No glasses	0.824	47.7%	0.883	0,836
	Glasses	0.765	41.1%	0.752	
85%	No glasses	0.353	76.4%	0.702	0,793
	Glasses	0.294	76.4%	0.588	

Note: SD = Standard deviation.

Table 5. Frowning

Intensity	GA	Mean	% Failures	SD	P
55%	No glasses	2.00	0.0%	0.000	*NaN
	Glasses	2.00	0.0%	0.000	
65%	No glasses	1.94	0.0%	0.243	0,073
	Glasses	1.65	5.8%	0.606	
75%	No glasses	1.65	11.7%	0.702	0,632
	Glasses	1.53	11.7%	0.717	
85%	No glasses	1.35	23.5%	0.862	1,000
	Glasses	1.35	17.6%	0.786	

Note: SD = Standard deviation.

Table 6. Closing the eyes tightly

Intensity	GA	Mean	% Failures	SD	P
55%	No glasses	2.00	0.0%	0.000	*NaN
	Glasses	2.00	0.0%	0.000	
65%	No glasses	2.00	0.0%	0.000	0,325
	Glasses	1.94	0.0%	0.243	
75%	No glasses	2.00	0.0%	0.000	*NaN
	Glasses	2.00	0.0%	0.000	
85%	No glasses	1.88	0.0%	0.332	1,000
	Glasses	1.88	0.0%	0.332	

Note: SD = Standard deviation.

For the "4-wrinkling the nose" exercise (refer to Table 7), there was evidence that the use of glasses may influence facial recognition ($p <= 0.05$) at intensities greater than 55%. It is observed that error rates are higher in the participants who wore glasses.

Table 7. Wrinkling the nose

Intensity	GA	Mean	% Failures	SD	P
55%	No glasses	1.647	5.8%	0.702	0,129
	Glasses	1.235	23.5%	0.831	
65%	No glasses	1.588	5.8%	0.618	0,060
	Glasses	1.118	23.5%	0.781	
75%	No glasses	1.529	5.8%	0.624	0,026
	Glasses	0.941	35.2%	0.827	
85%	No glasses	0.882	35.2%	0.781	0,035
	Glasses	0.353	70.5%	0.606	

Note: SD = Standard deviation.

The graphs presented in Figure 4 illustrate the results of the evaluation of the upper and middle portions of the face. As seen in the graphs, the greater the intensity of the movement on the face, the greater the occurrence of failures (average close to zero). Except for the "Wrinkling the nose" exercise, there is no difference between the groups (with and without glasses).

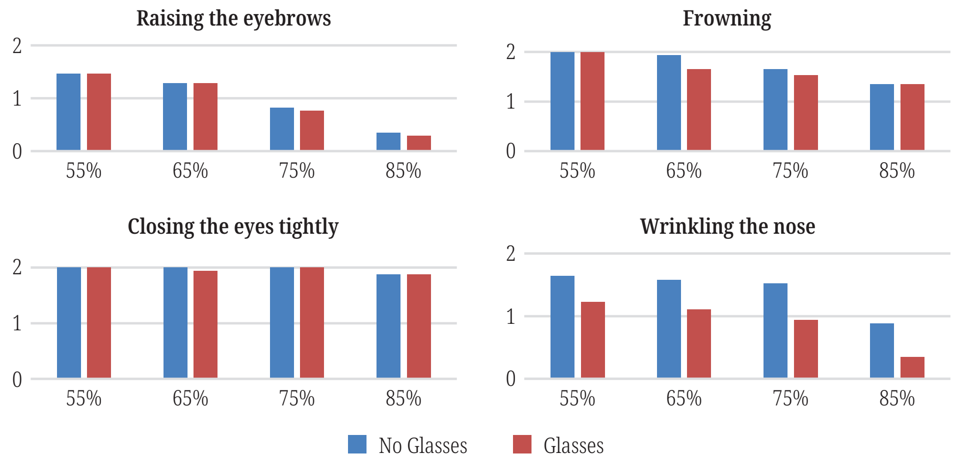

Fig. 4. Assessment of the upper and middle portion of the face

3.2 Assessment of the lower and middle portion of the face

In tests conducted on the lower and middle portion of the face, the influence of a beard and/or mustache on the software's accuracy in recognizing facial mimicry movements performed by the user was evaluated at intensities of 55%, 65%, 75%, and 85%.

It is noted that for the exercises "5 – lower lip protrusion" (refer to Table 8), "6 – compressing the lips" (refer to Table 9), "7 – smiling showing teeth" (Table 10) and "9 – Blowing out filling the cheeks" (refer to Table 11), there was no evidence that the use of beard and/or mustache could influence facial recognition in these exercises ($p >= 0.05$). The Tables show that both groups' success and failure rates are similar. As with GA, in GB, the higher the intensity, the higher the failure rate. Of all the exercises, "7-smiling showing teeth" (refer to Table 10) performed best, with zero failure rate.

Table 8. Lower lip protrusion

Intensity	GB	Mean	% Failures	SD	P
55%	No beard/mustache	1.52	10.0%	0.680	0,585
	Beard/mustache	1.38	15.0%	0.768	
65%	No beard/mustache	1.14	23.8%	0.793	0,760
	Beard/mustache	1.23	23.1%	0.832	
75%	No beard/mustache	1.10	33.3%	0.889	0,756
	Beard/mustache	1.00	30.7%	0.816	
85%	No beard/mustache	0.238	85.7%	0.625	0,388
	Beard/mustache	0.0769	92.3%	0.277	

Note: SD = Standard deviation.

Table 9. Compressing the lips

Intensity	GB	Mean	% Failures	SD	P
55%	No beard/mustache	1.95	0.0%	0.218	0,734
	Beard/mustache	1.92	0.0%	0.277	
65%	No beard/mustache	1.95	0.0%	0.218	0,734
	Beard/mustache	1.92	0.0%	0.277	
75%	No beard/mustache	2.00	0.0%	0.00	NaN
	Beard/mustache	2.00	0.0%	0.00	
85%	No beard/mustache	1.90	0.0%	0.301	0,194
	Beard/mustache	1.69	7.6%	0.630	

Note: SD = Standard deviation.

Table 10. Smiling showing teeth

Intensity	GB	Mean	% Failures	SD	P
55%	No beard/mustache	2.00	0.0%	0.000	NaN
	Beard/mustache	2.00	0.0%	0.000	
65%	No beard/mustache	2.00	0.0%	0.000	0,209
	Beard/mustache	1.92	0.0%	0.277	
75%	No beard/mustache	1.95	0.0%	0.218	0,440
	Beard/mustache	2.00	0.0%	0.000	
85%	No beard/mustache	1.71	0.0%	0.561	0,222
	Beard/mustache	1.92	0.0%	0.277	

Note: SD = Standard deviation.

Table 11. Blowing out filling the cheeks

Intensity	GB	Mean	% Failures	SD	P
55%	No beard/mustache	1.67	4.7%	0.577	0,399
	Beard/mustache	1.54	15.3%	0.776	
65%	No beard/mustache	1.67	4.7%	0.577	0,854
	Beard/mustache	1.46	23.0%	0.877	
75%	No beard/mustache	1.29	23.8%	0.845	0,416
	Beard/mustache	1.23	23.0%	0.832	
85%	No beard/mustache	1.05	42.8%	0.973	0,585
	Beard/mustache	0.769	46.1%	0.832	

Note: SD = Standard deviation.

For the exercise "8-smiling with lips together" (refer to Table 12), there was evidence that the use of beard and/or mustache can influence facial recognition ($p <= 0.05$) at an intensity greater than 75%. It is observed that the error rate is higher in the group without beard/mustache.

Table 12. Smiling with lips together

Intensity	GB	Mean	% Failures	SD	P
55%	No beard/mustache	2.00	0.0%	0.00	0,209
	Beard/mustache	1.85	7.6%	0.555	
65%	No beard/mustache	1.43	9.5%	0.676	0,265
	Beard/mustache	1.69	7.6%	0.630	
75%	No beard/mustache	1.38	23.8%	0.865	0,166
	Beard/mustache	1.77	7.6%	0.599	
85%	No beard/mustache	0.571	52.3%	0.676	0,005
	Beard/mustache	1.38	23.0%	0.870	

Note: SD = Standard deviation.

The graphs shown in Figure 5 illustrate the results of the assessment of the lower and middle portion of the face. As seen in the graphs, the greater the intensity of the movement on the face, the greater the occurrence of failures (average close to zero). Except for the "Smiling with lips together" exercise, there is no significant difference between the groups (No beard/mustache).

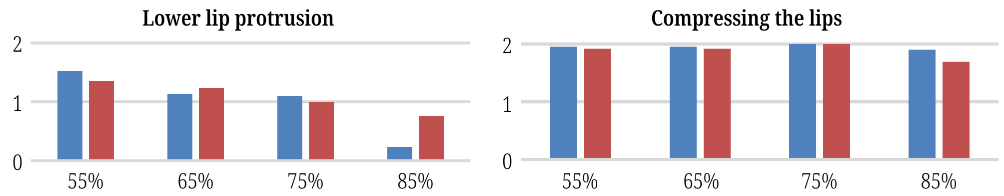

Fig. 5. *(Continued)*

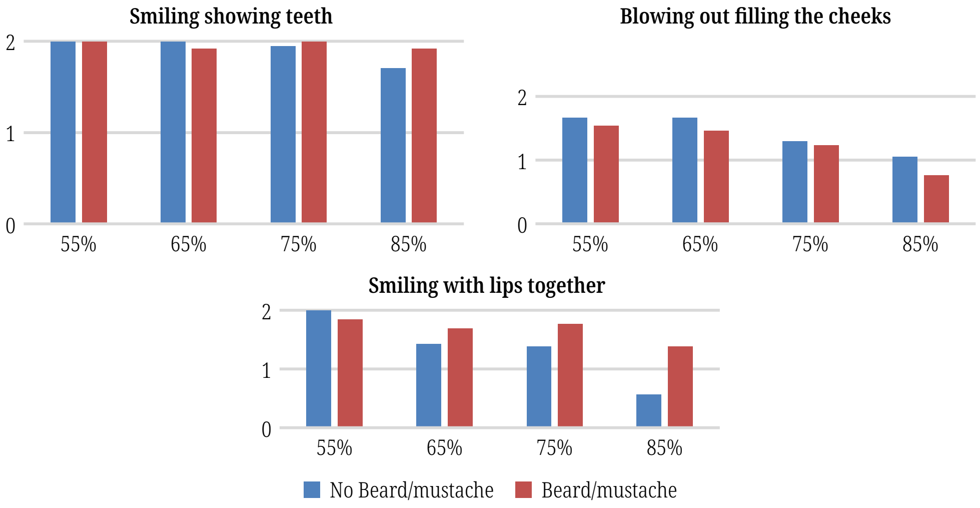

Fig. 5. Assessment of the lower and middle portion of the face

3.3 Participant overall satisfaction

The satisfaction questionnaire consisted of a selection of adjectives that users chose to describe their feelings after using the application. Participants had the option to check the adjectives that best reflected their experiences, including words such as "Happy," "Satisfied," "Relaxed," "Surprised," "Bored," "Tired," "Discouraged," "Irritated," and "Insecure." This approach allowed for a quantitative assessment of participants' responses, providing insights into their overall satisfaction with the app.

Additionally, for a more comprehensive understanding, we combined quantitative satisfaction data with qualitative insights collected through participant feedback. This joint analysis revealed valuable insights into the user experience and areas in need of improvement.

- Most participants expressed positive feelings towards the app. The terms "Content," "Satisfied," and "Relaxed" appear significantly frequently in responses (see Figure 6), suggesting that use of the app was generally well received.
- Some participants mentioned feeling "Bored" or "Tired." This can be attributed to the intensity of the exercises, especially when performed at a maximum level of 75%. Considering including other exercises, as suggested by one participant, can provide a variety of tasks and prevent fatigue.
- Qualitative comments highlighted the importance of sound feedback. Several participants expressed a desire for auditory feedback that indicates task success, particularly when performed with eyes closed. The lack of this feedback can lead to a feeling of boredom and a lack of motivation while using the app.
- One of the participants mentioned that the application did not adequately transmit the effort of the movements. This highlights the need to include visual or haptic feedback that helps users realize the effectiveness of their efforts while using the app.

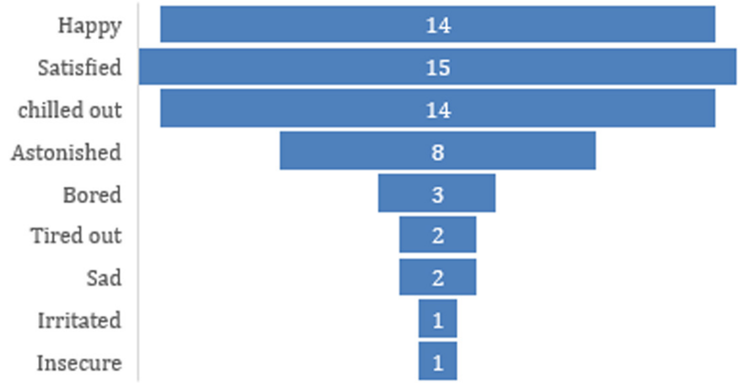

Fig. 6. Level of satisfaction among the users of Fisiobem app

4 DISCUSSIONS

We undertook an efficacy study of the Fisiobem app, designed for PFP rehabilitation, by performing facial mimicry at 55%, 65%, 75%, and 85% ROMs. Our results highlight interesting performance patterns and how these factors can influence the accuracy of facial recognition software.

In the evaluation of the upper and middle portions of the face, we observed that the "raising the eyebrows," "frowning," and "closing the eyes tightly" exercises were not significantly affected by the use of glasses. The success and failure rates for these exercises remained consistent for both groups (with glasses and without glasses), indicating that the facial recognition software demonstrated robustness in this respect. However, when analyzing the "wrinkling the nose" exercise, we identified evidence that wearing glasses impacted facial recognition, particularly at intensities above 55%. The failure rates were higher in the group that wore glasses, suggesting that the presence of glasses may affect the software's accuracy in this specific context.

It is worth mentioning that one of the participants reported having had botox applied to the forehead region for aesthetic purposes, causing relaxation of the muscles in the region of application. This fact hindered the participant's ability to perform the "1-raising the eyebrows" exercise. Recalculating the failure rate of the group without glasses, excluding this participant, showed that the percentage of failures in both groups was closer to the values shown in Table 4.

When evaluating the lower and middle portions of the face, the exercises "lower lip protrusion," "compressing the lips," "smiling and showing teeth," and "blowing out and filling the cheeks" did not present significant differences in facial recognition between the groups with and without a beard or mustache. These results indicate that beard and/or mustache did not substantially affect the software's ability to recognize facial mimicry movements for these exercises.

However, we observed that the "smiling with lips together" exercise was sensitive to the presence of a beard or mustache, especially at intensities greater than 75%. In these cases, the failure rate was higher in the group without a beard or mustache. This result suggests that the beard region may provide sufficient contrast for better detection by the facial recognition algorithm, raising interesting questions about how facial features interact with recognition software.

Our results suggest that using glasses may influence facial recognition in certain contexts. At the same time, a beard and/or mustache may have variable effects depending on the exercise and intensity. These findings have important implications for developing more robust and adaptable facial recognition systems. Yet, further research with larger and more diverse samples is necessary to validate and generalize these findings and explore the nuances underlying the interactions between facial features and recognition algorithms.

The quantitative data and participants' comments in the study demonstrate that "Fisiobem" has the potential to be a valuable tool in the rehabilitation of PFP. In the tests conducted, the app exhibited good accuracy in detecting facial mimicry exercises traditionally used in the rehabilitation process of PFP. This study also revealed that in the context of rehabilitating individuals with PFP, the app allows the responsible therapist to adjust the exercise intensity independently of patient characteristics such as beard, mustache, or glasses.

Another important assessment in the study regarding the app's applicability in rehabilitation is determining the maximum intensity limit that can be worked with this tool. Exercises such as raising eyebrows, wrinkling the nose, and protrusion of the lower lip had a high percentage of failures stemming from the facial recognition process, which may negatively impact users' motivation during the rehabilitation process.

An important limitation of this study is the sample size and the lack of consideration of the diversity of skin tones among the participants. The study recognizes that the influence of glasses and beard/mustache on facial recognition ability can vary significantly between individuals with different ethnic characteristics and skin tones. Therefore, the results presented here may not be generalizable to broader and more diverse populations. Including a more representative sample in terms of size and ethnic diversity could provide more comprehensive insights into how these factors affect the accuracy of facial recognition algorithms, thus contributing to a more complete understanding of the landscape.

The insights generated in this study allow us to recommend future research in facial rehabilitation including:

1. Investigating the effectiveness of voice feedback in conjunction with visual feedback in the "Fisiobem" app. This could provide additional auditory cues to guide patients' exercise performance and enhance the overall rehabilitation experience.
2. Conducting studies to evaluate the impact of visual feedback, such as real-time video guidance or augmented reality, on the accuracy and effectiveness of facial mimicry exercises. This could help determine whether more immersive visual feedback can improve patients' engagement and progress in their rehabilitation journey.
3. Exploring the role of gamification techniques in the "Fisiobem" app and their potential to enhance motivation and adherence to the rehabilitation program. This could involve incorporating elements like rewards, challenges, or social interaction to make the exercises more enjoyable and encourage long-term participation.
4. Examining the effects of different exercise diversification techniques on patient outcomes. This could involve investigating the benefits of introducing new exercises, varying exercise intensities, or incorporating progressive difficulty levels to continually challenge and stimulate patients' facial muscles.
5. Considering the influence of factors such as age, gender, and cultural background on the efficacy of the "Fisiobem" app. Understanding how these variables may affect patients' response to the app's rehabilitation program can help tailor the treatment to different demographic groups for better overall outcomes.

By addressing these research areas, we can further improve the "Fisiobem" app's functionality, user experience, and therapeutic benefits. Conducting larger-scale studies with diverse populations will provide a more comprehensive understanding of the effects of different feedback modalities and exercise diversification techniques, ultimately advancing the field of technology-assisted facial rehabilitation.

5 ACKNOWLEDGMENT

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