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Development of an open-source and free facial rehabilitation website for severe Bell's palsy: a within-subject study on user experience and patient's compliance with the MEPP-website

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Implications for Rehabilitation

- Recent data suggests that mirror effect therapy combined with drug therapy supports the recovery of severe Bell's Palsy.
- The specialized Mirror Effect Plus Protocol (MEPP)- website is a clinical computer-based tool developed to promote patients' motor learning and diminish cognitive load during mirror therapy.
- The MEPP-website increase clinicians' accessibility to a specialized facial rehabilitation tool for mirror therapy.
- Clinicians using the MEPP-website can also objectively and easily measure compliance to facial therapy with the MEPP-website.

Title

Development of an open-source and free facial rehabilitation website for severe Bell's palsy: a within-subject study on user experience and patients' compliance with the MEPP-website

Running Head: MEPP-website

Abstract

Purpose: An open source and free website called Mirror Effect Plus Protocol (MEPP)-website was developed with features to diminish cognitive load and support motor learning during facial exercises. Assessing patient's perceptions is crucial when developing rehabilitation tools because patients' willingness to use the tools strongly affect engagement in the rehabilitation process. This study compared clinicians' and patients' user experience with the MEPP-website versus a hobby-designed website.

Materials and Methods: Ten patients with acute severe Bell's palsy and five clinicians were enrolled in a within-subject and crossover design. User experience was assessed with the Modular evaluation of Components of User Experience questionnaire. Wilcoxon-Signed-Rank test analysed user experience, and descriptive analyses explored the order effect. Therapeutic compliance was verified for the MEPP-website by an integrated feature. Clinicians' descriptive statistics and subjective observations were also reported.

Results: Both patients and clinicians demonstrated a preference for the MEPP-website, whether they used it first or second. Despite this preference, compliance with the MEPP-website was reduced, although it tended to be better when used first.

Conclusions: MEPP- website during facial rehabilitation improved user experience. Better user experience likely optimizes how patients perform and facilitate their exercises. Factors affecting compliance with facial rehabilitation remain to be addressed.

Keywords: Bell's palsy, facial nerve, facial rehabilitation, mirror therapy, peripheral facial palsy

Introduction

Bell's palsy

Bell's palsy (BP) is one of the most common causes of abrupt onset of unilateral facial weakness in addition to stroke [1]. It is well documented that BP can have dramatic impacts on the lives of those affected, especially in incomplete recovery, when patients may be left with permanent disfiguring facial weakness, hemifacial spasms, and synkinesis [1,2]. Facial rehabilitation programs such as neuromuscular retraining [NMR; 3] and mime therapy [4] have long been recognized as efficient for the treatment of permanent sequelae in chronic BP [5]. Additionally, a growing body of research has demonstrated the beneficial effects of *early* facial rehabilitation (combined with drug therapy) to support the recovery of BP [6-8]. If provided as early as two weeks after onset, facial rehabilitation could lead to better recovery with long-lasting effects [6].

Irrespective of whether they are designed for acute or chronic BP, most facial rehabilitation programs [9,10] integrate, at least at some point during the process, the use of a traditional mirror, to allow patients to observe and analyze their facial movements [11]. However, working with a traditional mirror during facial rehabilitation may present disadvantages over time. The mismatch between the visual input of the affected side of the face provided by the mirror and the motor input applied during the exercises could lead to maladaptive muscle hyperactivity and compensation [12-14]. The use of a real mirror has also been identified as a barrier to patients' achievement of a high rate of adherence to therapy [15], probably because it sends an altered, confrontational image to the patients while they attempt to undergo therapy [16].

Therefore, a mirror effect therapy has been developed to address these issues by providing corrected mirror visual feedback instead of only a patient's reflection during exercises [12]. With the help of a mirror-book or computer-based program, the modified mirror effect adjusts the visual biofeedback during motor exercises by duplicating the healthy side of the face or any other parts of the body, resulting in a symmetrical movement and correction of the resulting visual afferences. This type of mirror therapy has been found beneficial in the treatment of phantom limb pain and paralysis [17] and stroke-induced hemiparesis [14]. The principle of mirror therapy has recently been applied for treatment of facial palsy: patients were asked to perform facial exercises while observing a display of a modified version of their faces. Data suggests that mirror effect therapy was helpful to improve facial function in patients who underwent a facial corrective surgery called temporal lengthening myoplasty [16] and also in patients with peripheral facial nerve palsy from different aetiologies [7,18,19]. Because facial and limb muscles are differently constituted (i.e. facial muscles have no spindles, have connexions with limbic system, etc.), instructions given during facial mirror effect therapy has to be adapted to this reality [7]. With adapted instructions, patients can learn from multiple adequate facial motor responses though the mirror effect, and avoid unnecessary muscular overcompensation [7,19].

Computer-based tools constitute an interesting way to provide mirror effect, as they can be utilized autonomously at home by patients, compared to a set-up made of several real mirrors together to create a mirror effect [12]. Our team developed a facial rehabilitation protocol called the Mirror Effect Plus Protocol (MEPP) specifically designed for acute BP, which combines the advantages of mime therapy and NMR with the modified visual biofeedback from a modified mirror effect [for a complete description of MEPP see 20]. MEPP requires the use of a computer to duplicate the healthy hemiface of patients during facial exercises. During the development of the MEPP therapy, we lacked a free computer-based program adapted for clinical use to create modified visual feedback during facial exercises. A free hobby-

designed website named Webcamtoy® (www.webcamtoy.com; WCT) was first used, as it allows the replication of the preserved half of the face to the paralyzed side. Given that the website was not developed for therapy purposes, it has some limitations. First, patients had to choose which side of the face should be replicated by themselves. They also needed to refer to an off-line exercise sheet provided by the clinician, as the website did not allow the addition of instructions. Because patients already needed to be highly focused on the specificity of their facial movements, proprioception, and visual feedback, managing both an exercise's sheet and the website was overwhelming. Furthermore, they needed to concentrate on the timing of the exercises and to pick up exercises randomly on their own (in accordance with the principle of randomized practice), which could lead to an imbalance in the rehabilitation [21,22]. Altogether, these factors increase the extraneous complexity and interruptions of the therapy, which are factors that could contribute to a high cognitive load, thereby undermining users' ability to engage in the high-level, integrative thinking needed for facial therapy [23]. This, in turn, could eventually lead to decreased compliance and poorer outcomes in facial rehabilitation [24-26].

Compliance or adherence to treatment is an important factor to measure, as poor compliance can negatively influence outcomes and healthcare costs [15,25]. Objective measures of compliance are needed for clinical and research purposes, as they can help alleviate the variation in and inaccuracy of patients' self-rated measures [25]. Without objective measures of compliance, adherence to treatment can be difficult to observe because it requires clinicians to rely on what could be recalled inaccurately by patients [15].

Development of a MEPP-website

To compensate for these difficulties, we developed a specialized website adapted to facial rehabilitation. The MEPP-website should optimize the way patients perform their exercises and should facilitate clinicians' work via its many integrated features. First, the MEPP-website allows the creation of separate clinician and patient accounts. From their account, clinicians can preprogram which side of the face has to be replicated, reducing the risk of having a patient choose the wrong side for the autonomous home sessions. Additionally, clinicians can determine and assess the relevant facial exercises required specifically for each patient, also allowing the modification of the exercise program along with the progress of the patient. Clinicians can also follow patients' compliance through a feature that records an entry in the personal history of the patient each time they log into their profile to complete the therapy, and each time they finish a session. This allows for an objective measure of patient compliance. Moreover, the MEPP-website was developed to have every instruction appear on the screen during each exercise, including emotional cueing that helps elicit a more natural movement [4] at a specific pace. As mentioned earlier, the chosen pace should favor an ideal rhythm of execution in which each repetition respects the ideal contraction/rest time ratio for the facial muscles, as well as allowing enough time to concentrate on the facial sensations. Additionally, the website randomizes the exercises, allowing optimal randomized practice conditions. Thus, the interface and features of the MEPP were designed to reduce extraneous complexity and interruptions during therapy, which should diminish cognitive load and help patients concentrate on their facial exercises, thereby encouraging good compliance [23]. The MEPP-website is intended to be open source and available for free once development is completed. It is well known that subjective factors such as perceptions, judgments, emotions, motivation, and personal values influence the likelihood of a system being used and integrated into everyday life [27]. These subjective impressions can differ significantly from usability-oriented performance data [28]. Thus, evaluating the user experience is crucial for the development of a novel technical system.

This study aimed to investigate the user experience of our new customized and open-source MEPP-website among patients with BP and clinicians. The patients and clinicians completed the MeCUE questionnaire, an adaptable, validated questionnaire of user experience [29] which has already been used to investigate the user experience of patients with facial palsy [12], to compare the new customized MEPP-website and the non-specific WCT for MEPP rehabilitation. First, considering that the MEPP-website was specifically designed for MEPP rehabilitation and that it offered additional relevant features for facial rehabilitation, we hypothesized that it would facilitate a better user experience than could WCT, in patients and clinicians. Second, thanks to the cross-over design, we explored a potential order effect that could have affected patients' user experience, with descriptive statistics. Third, we described compliance to therapy with an integrated feature of the MEPP-website, that allowed to objectively measure this parameter for this webtool. Finally, order effect for compliance with the MEPP-website was analysed with descriptive statistics.

Methods

Patient Participants

Ten patients who were recruited for a larger longitudinal study aiming to estimate the efficacy of the MEPP (ethics approval number: MP-32-2017-1365) participated in this study. The demographic information is summarized in table 1. These patients were originally referred by otorhinolaryngologists and emergency physicians working at CIUSSS de l'Est-de-l'Île-de-Montréal and CIUSSS du Nord-de-l'Île-de-Montréal. The patients who were randomly assigned to the mirror effect rehabilitation group in the larger study were selected to use both WCT and the MEPP-website when it became available. The patients were recruited according to the following inclusion criteria: (1) age 18 years or older, (2) acute

severe BP for under 10 days, and (3) having received the following standardized drug therapy: prednisone 50 mg per day for 10 days and valacyclovir 1000 mg three times a day for 7 days, prescribed within 72 hours of onset. The exclusion criteria were: (1) medical history of facial nerve trauma, (2) previous BP or other facial paralysis, (3) history of cognitive impairment or disorder (e.g., stroke, neurodegenerative diseases), (4) psychiatric disorder requiring active monitoring (e.g., severe depression, schizophrenia), (5) medical history of neoplastic disorders, and (6) bilateral facial palsy. All patients were informed of the purpose of their participation and provided written and informed consent prior to enrollment.

Clinician Participants

Clinicians were enrolled to form an advisory committee to evaluate user experience with both the MEPP-website and WCT from the clinician's point of view. They were recruited via email from various hospitals and rehabilitation centers in Quebec. They were selected for their interest and expertise in peripheral facial palsy interventions. The purpose of this committee was to use both web tools in clinical settings and to give their comparative impressions about user experiences, after using each website for facial rehabilitation for a short trial period.

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Insert table 1 approximately here.

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Study design

Figure 1 shows a flowchart of the study. A within-subject design trial was employed to compare user experience in interaction with both websites. A crossover design was also chosen for the patients with BP to control for potential order effects. Patients were assigned to one of the following groups: group AB started with the hobby-designed website WCT and group BA with the MEPP-website. The first mirroring system was used for at least 2 to 4 weeks of facial rehabilitation. User experience was then assessed for the first website. The second system was then introduced and used at least for 2 to 4 weeks, after which user experience was assessed for the second website. For clinicians, no crossover design was used to give them more freedom to use the websites at their convenience in the challenging clinical context of the COVID-19 pandemic. Instead, all the clinicians met once for an explanation of how both websites worked. They were then given an eight-week trial period during which they had to use each website numerous times, set up a patient account on the MEPP site, and run a facial therapy program with both websites and with a real patient. The clinicians were told that each website had advantages and disadvantages and that their comments on each website and their preferences would be gathered at the end of the given period. At the end of the trial, we met with each clinician individually so that they could complete the MeCUE [29] twice (one for each website) and provide specific comments about the advantages and disadvantages of each website.

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Therapy

In this study, the MEPP was used to provide facial rehabilitation to all participants with BP. MEPP is a therapy specifically designed to treat acute severe BP [for a complete description see 20]. Briefly, it

consists of counseling, motor imagery, and facial retraining with a mirror effect. Counseling is provided during the first sessions of treatment and consists of a basic overall introduction to facial function and anatomy. Motor imagery sessions are then provided, and patients learn passive tissue manipulation. Specific facial exercises are then explained using the principles of NMR [30] and practiced with the help of either one of the two websites. The facial exercises presented to the patients are chosen according to individual deficits. Retraining is performed at home, where patients perform the previously explained muscle exercises using one of the two websites until recovery. To favor motor learning, to avoid muscle fatigue and to conform to principles reported in facial rehabilitation literature [8,22,31], patients are asked to apply a distributed practise, through two short sessions of 15 minutes of facial rehabilitation everyday.

Websites

As mentioned previously, the two websites were tested by clinicians and patients. Each website uses computer vision technologies to provide patients with a symmetrical facial picture (see figure 2). The two websites produce similar pictures because they both use the same technological strategy to present a modified visual feedback of the face, i.e., mirroring based on the central axis of the image. Although both websites share a purpose and produce similar images, their discrepancy resides in the features they offer, as explained previously.

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Outcome measures: MeCUE questionnaire, subjective impressions, and compliance

First, to compare and assess user experience with the two facial mirroring systems, the user experience questionnaire (MeCUE: Modular evaluation of Components of User Experience; http://mecue.de/) was used. This questionnaire was chosen because it constitutes an adaptable, complete, and validated questionnaire of user experience [27]. The MeCUE questionnaire is composed of four modules that were created to assess key components of user experience: product perception, user emotions, consequences of usage, and global judgment. This questionnaire was validated in a way that allows researchers to select relevant modules to assess and remove some of the modules without affecting the validity [27]. Three of these modules were selected because the second module, which centers on user emotions, includes questions that do not apply to a product designed for clinical purposes (e.g., the product makes me feel euphoric). The second module also presents items with low psychometric quality [32] and includes items that could not assess user experience exclusively when considering the context in which the product was used, i.e., facial muscular retraining (e.g., "When using this product, I feel exhausted."). Some items from the subscales "commitment" and "status" of the first module were also removed given their poor fit with the context of therapeutic usage of the system (e.g., "I would not mind if my friends envied me for this product."). Finally, items on the "visual aesthetics" subscale were also removed because visual design was not deemed a key factor differentiating the websites; their distinction rested in instrumental rather than non-instrumental properties. The subscales that were retained and analyzed as dependent variables were usefulness, usability, product loyalty, intention to use, and overall evaluation. The same modules were used for the clinicians.

Additionally, compliance to therapy was measured for the MEPP-website through an intrinsic functionality. Specifically, a history of logins and completed sessions for each patient was recorded on

the website. No comparisons were made with compliance to WCT, as no objective and comparable measures were available for this website.

Finally, subjective impressions were gathered informally from the clinicians at the end of their 8-week trial regarding the advantages and disadvantages of each system; specifically, they had to answer the following questions: “What did you prefer while using the (MEPP/WCT) website?” and “What could have been better in the (MEPP/WCT) website?”

Data analysis

All statistical analyses were performed using XLSTAT version 2021.1 (Addinsoft, Paris). As prescribed by the authors of the MeCUE, a mean value for each subscale of the MeCUE questionnaire was first calculated for each patient [29]. The data was analyzed using descriptive statistics for each MeCUE variable for both patients and clinicians. The Wilcoxon signed test for matched samples was then used to analyze intra-subject differences in patients’ user experience between the two websites for each MeCUE subscale with a *p*-value of 0.05 indicating statistical significance. This nonparametric test was conducted because the assumption of a normal distribution could not be met, considering the limited sample size. Next, to explore the presence of an order effect in user experience, descriptive statistics were extracted between users who utilized the MEPP-website first (n=6) and second (n=4), and between users who utilized WCT first (n=4) and second (n=6).

Compliance to the MEPP-website was obtained by extracting the number of completed treatment sessions per day per patient for the first 14 days of use (the minimum required length of treatment for each system). As each patient was asked to perform two short sessions of 15 minutes of exercise per day, we extracted the number of completed sessions for a total of 28 recommended sessions. If patients

performed more than two sessions per day, every extra session contributed to the total until a maximum of 28 sessions was achieved. Initiated but incomplete sessions were discarded. We then explored descriptive data about the total number of completed sessions to assess for a potential order effect. No data on compliance was gathered regarding WCT because there was no comparative feature that allowed for equivalent analysis. Finally, qualitative feedback from clinicians was gathered and reported in an Excel table for global appreciation and purpose of comparison. No hypothesis testing was undertaken for any inter-subject comparisons (with patients or clinicians), considering the small sample size.

Results

Eleven patients [females, 7; median (interquartile range or IQR) age, 49 (15,5) years; left-sided facial palsy, 4; House-Brackmann median score, 5] and five clinicians [females, 5; median (IQR) age, 32 (16); years of experience in field (range), 13(2–30)] were initially enrolled. One patient in group AB failed to complete the questionnaires. Thus, the analysis was conducted on the ten remaining patients. The raw data are presented for each patient and clinician on each measured variable in Supplementary Material Document 1. The descriptive data in A) shows that patients and clinicians appear to prefer the MEPP-website in four of five modules: usefulness, intention to use, product loyalty, and overall evaluation. Also, median and IQR range values about a potential order effect in B) demonstrated no differences between patients who used MEPP first vs second, and patients who used WCT first vs second, for any of the measured variable. Figure 3 illustrates the preference of both clinicians and patients for the MEPP-website using box plots of three representative modules of the MeCUE (usefulness, intention to use, and overall evaluation). Figure 3 also shows that MEPP was attributed higher ratings by both clinicians and patients in all three modules. Conversely, there were no differences between the two websites in terms of usability [global median score of 6 for WCT and of 7 for MEPP in patients; 5.67 for WCT and 5.33

for MEPP in clinicians]. In other words, each website attained high ratings for this module. As demonstrated in table 2, the results of the Wilcoxon signed test demonstrated that patients significantly preferred the MEPP-website in terms of usefulness ($V = 1$; $p = 0{,}017$), intention to use ($V = 6$; $p = 0{,}028$), product loyalty ($V = 3{,}5$; $p = 0{,}024$), and overall evaluation ($V = 0$; $p = 0{,}011$) compared to the hobby-designed website. However, the difference was not significant for the usability subscale ($V = 1{,}5$; $p = 0{,}058$).

The results regarding compliance are presented in Supplementary Material Document 2. Globally, only four patients (P6, P7, P10, and P11) conformed to the recommended schedule of therapy (two completed sessions per day) during the verified timeframe. Patient 5 only practiced twice during a two-week period, while patients 8 and 9 only practiced three and five times, respectively. Compliance with the MEPP-website can thus be qualified as reduced, even if patients clearly mentioned their preference for this web tool. As for compliance with the MEPP-website, exploration of the order effect with descriptive statistics tends to show that compliance was higher in the group where the MEPP-website was used first [median number of completed sessions, 26 (IQR = 17.25) vs 6.5 (IQR = 2.75) than in the group where it was used second]. Indeed, four of the six patients who used the MEPP-website first mostly conformed to the recommended schedule of therapy. No patients who used the MEPP-website after WCT conformed to the parameters of therapy.

A summary of the information about of the advantages and disadvantages of each system expressed by clinicians are presented in table 3. Concrete examples are also reported in Supplementary material 3. All clinicians found each website relatively easy to use, although clinician 5 reported that navigation was not intuitive on the MEPP-website. For the MEPP-website, the quality of the instructions for facial exercises (i.e., their appropriateness in terms of font, color, and ease of understanding) was a recurring topic and

appeared to be an advantage of this tool for clinicians. It was reported that the MEPP-website was better in terms of many therapeutic parameters (measures of compliance, follow-up, adaptability of the therapy according to progress, etc.). WCT being usable on mobile devices was an advantage for that website. Clinicians also noted for both websites that their patients presented difficulties in maintaining their head stability in the central axis for optimal reduplication of the unaffected side during the exercises.

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Insert figure 3, table 2, and table 3 approximately here.

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Discussion

Consistent with our hypothesis, the patients rated almost all the subscales of user experience (usefulness, product loyalty, intention of use, and overall rating) significantly higher for the MEPP-website, with no order effect. The descriptive results of the MeCUE and subjective impressions of the clinician users exhibited a similar trend, with a numerical preference for MEPP in all categories except for usability. Despite patients' preference for the MEPP-website, compliance was reduced with this web tool.

The patients rated the usefulness of the MEPP-website significantly higher than that of WCT. This indicates that the therapeutic website was of greater help for users to meet their goals, which is the key factor in usefulness according to the original definition of Thüring and Mahlke [33]. The MEPP-website was also assigned significantly higher scores regarding the other modules assessed (i.e., intention to use, product loyalty, and overall rating) by both clinicians and patients, suggesting that patients and clinicians would choose the MEPP-website over WCT if given the option. The fact that the overall module was

significantly higher also indicates that even though usability was not rated significantly higher for the MEPP-website, both patients and clinicians preferred it to WCT.

We hypothesized that the MEPP-website accommodates patients in performing therapy by reducing interruptions (e.g., managing instruction sheets), which in turn increases the patient's performance and focus on the main task [23]. It is known that when a computer system is designed to reduce cognitive load, the user satisfaction and motivation to use the product again are increased [34]. This suggests that the added features of the MEPP-website contributed to diminishing patients' cognitive load, resulting in a more favorable user experience [23]. Perhaps surprisingly, the rating of the usability did not differ significantly between the MEPP-website and WCT. The original definition of usability by Thüring and Mahlke [33] refers to the ease, efficiency, and effectiveness with which a user interacts with and learns to use a product. In the MeCUE, usability is measured using the following statements: "The product is easy to use," "It is quickly apparent how to use the product," and "The operating procedures of the product are simple to understand" [27]. Users' perception of usability is influenced by a product's navigation system and terminology [35]. Based on these observations, two potential causes for the lack of significant differences between the two websites were identified. First, the navigation system of each website is relatively simple and quick to master. The fact that both websites were attributed high usability supports this hypothesis. Indeed, navigating the MEPP-website and WCT only requires a few clicks to reach the facial mirroring page. Second, while displaying similar technology for reduplication of the healthy hemiface over the paralyzed one, the websites did not differ in terms of efficiency of the system. Each system presents difficulties in stabilizing the face during therapy, as reported by our clinicians.

The present study also found no order effect in any of the user experience components in patients with descriptive statistics. An order effect would have been likely to occur because the perceived advantages

of the MEPP-website's added features (e.g., display of instructions and visuals for timed contractions and rest) could have been lessened if this website was used second (because of patients' familiarity with the therapy). However, descriptive statistics suggest otherwise than such an effect. Even if patients likely retained some elements of the protocol by memory, it did not influence their appreciation of the MEPP-website in comparison to WCT; the former was still perceived as superior to the latter.

Additionally, we objectively measured patients' compliance with the MEPP-website, as compliance is an important factor for success in facial rehabilitation [24]. A globally low compliance to therapy was found through the MEPP-website data, even though patients reported a preference for that webtool. Furthermore, we could not establish a comparison with the therapy through WCT, as the latter website does not offer the functionality to observe patients' login history. Consequently, we could not comment on compliance with the WCT. However, WCT received globally poorer ratings in terms of user experience than did the MEPP-website, and this represents a factor that could affect day-to-day use [23]. Low compliance with facial reeducation has been reported previously and was mostly attributed to a lack of commitment due to other responsibilities such as professional occupation [24]. We observed a similar phenomenon, as two of the four committed and compliant patients in this study were retired adults with fewer professional responsibilities. Additionally, a recent study reported varying levels of self-reported adherence to facial rehabilitation, with only approximately 30% of the participants (32/97) demonstrating very high adherence [15], which is in accordance with our findings. One of the main factors preventing high compliance reported by the participants was "difficulties in fitting facial exercises into daily life" [15]. Descriptive data suggests that compliance was higher in the group that used the MEPP-website first, with four of six patients being compliant. One possible explanation for the relatively low global compliance is that compliance is high at the onset of therapy but diminishes over time as patients recover. In fact, four of our non-compliant patients were those who initiated therapy with WCT due to the

crossover design. They may have become less compliant with the therapy by the time they started to use the MEPP-website. Other factors such as severity at onset could explain the lack of adherence, with three of six non-compliant patients having a severity of 4 in the Facial Nerve Grading System (FNGS) at the onset. Nevertheless, one of the greatest advantages of the MEPP-website (as reported by clinicians) is that it presents a functionality that assesses compliance objectively.

Finally, clinicians were asked to provide input on their experience with both websites in a more informal setting. Some stated that while they preferred the MEPP-website overall, they found WCT more practical because it could be used on other devices such as digital tablets and smartphones. Users also reported difficulties in maintaining facial stability while performing facial exercises with both websites. Maintaining an adequate posture for optimal face mirroring feedback is indeed tedious with the conventional technology, which consists of duplication (reduplication) based on the central axis of the image. Making the website available on multiple devices and resolving facial stability issues are considered key changes that can greatly increase user satisfaction. Incorporating augmented reality techniques, such as appearance mirroring and muscle mirroring, as used for computer vision technology-based face mirroring systems [12], could potentially improve user experience and concentration on facial tasks. Since augmented reality technology provides a more organic and realistic face rendition, it could also have positive impacts on embodiment and motor learning [12], which are core principles in MEPP therapy. In a future study that would compare different facial reduplication technologies, it would be important to assess the patients' differences in facial visual representations and embodiment experience with a validated tool, such as an adaptation of the Virtual Embodiment Questionnaire [36].

This study had some limitations. First, the main limitation of the present study is the low number of participants and clinicians, which limits the conclusions that can be drawn from our results. For example,

clinicians' impressions can't be generalized. With regard to the general prevalence of BP and the relative rarity of severe and persistent cases, the sample size in this study remains fair. International recruitment of expert clinicians could be considered in a future study. Second, although we considered investigating the impact of the mirroring system on facial improvements, we elected not to process the associated data because of the small patient sample size, variability in treatment length (2 to 4 weeks, dependent on the progress of BP), and relative variability of severity at onset (grades 4 to 6, FNGS 2.0). Furthermore, it would have been interesting to control the order effect in the clinicians as well. Lastly, age of the participants varies much and could have potentially induced a bias given an eventual difference in interests or easiness in technology usage among participants.

Conclusion

This study suggests that the user experience of the specialized MEPP-website used to perform facial rehabilitation is better than is that of a hobby-designed website (here, WCT). The advantages of the MEPP-website reside in its many specific functionalities, which assist both clinicians and participants in the rehabilitation process, probably with a lesser cognitive load dedicated to the management of the therapy. Concretely, as the instructions, pace, and randomization of facial exercises are provided by the website, patients can focus on facial motor learning and better achieving their goals of working on their facial functions. Clinicians can follow their patients' progress, evaluate patient compliance, and adapt each therapy based on a personalized profile they create for therapeutic goals.

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Declaration of interest

The authors report no conflicts of interest. The MEPP-website is free and open-source, thus no financial gains are possible.

Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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Tables

Table 1. *Demographic data about patients*

Patient	Sex	BP side	Age	Schooling years	FNGS 2.0 grade at onset	SB score at onset	First website used
P1	F	L	38	13 years and more	6	10	WCT
P2	F	R	19	< or = to 12 years	4	56	WCT
P3	F	R	29	13 years and more	6	8	WCT
P4	F	R	19	< or = to 12 years	5	18	WCT
P5	M	R	75	13 years and more	4	44	WCT
P6	F	R	43	< or = to 12 years	5	27	MEPP ws
P7	M	L	68	13 years and more	5	33	MEPP ws
P8	F	L	58	13 years and more	4	54	MEPP ws
P9	M	R	29	< or = to 12 years	5	23	MEPP ws
P10	M	L	53	13 years and more	5	29	MEPP ws
P11	F	R	49	13 years and more	5	28	MEPP ws

Legend: BP: Bell's palsy; FNGS 2.0: Facial Nerve Grading System 2.0; WCT: Webcamtoy; MEPPws: MEPP-website; FNGS 2.0 scores: 6= total palsy; 1= normal facial function. Sunnybrook (SB) scores: 0= total palsy; 100= normal facial function

Table 2. *Intra-subject differences between scores for each subscale of the MeCUE for both MEPP-website and WCT used first with Wilcoxon tests values for effect of webtool on user experience,*

Modules	Subscale	Patients	Δ in scores	V	*p*
Perception	Usefulness	P6	-0,67	1	**0.017**
		P7	0		
		P8	0		
		P9	-1,33		
		P10	-4		
		P11	0,34		
		P2	-2		
		P3	-1		
		P4	-1,67		
		P5	-1,67		
	Usability	P6	0	1.500	0.058
		P7	0,67		
		P8	0		
		P9	0		
		P10	-3		
		P11	0		
		P2	-1,67		
		P3	-1		
		P4	-0,67		
		P5	-2,33		
Usage	Product loyalty	P6	-2,66	3.500	**0.024**
		P7	-1		
		P8	0,67		
		P9	-2,67		
		P10	-3,67		
		P11	-1,33		
		P2	-3,33		
		P3	-3,67		
		P4	0		
		P5	1		
	Intention to use	P6	-1,44	6	**0.028**
		P7	-0,34		
		P8	2		
		P9	-2		
		P10	-5		
		P11	-2		
		P2	-3,34		
		P3	-3,67		
		P4	-1,33		
		P5	-0,34		
Overall evaluation		P6	-2	0	**0.011**
		P7	-1		
		P8	0		
		P9	-5		
		P10	-7		
		P11	-1		
		P2	-3,5		
		P3	0		
		P4	-1,5		
		P5	-1		

Legend: WCT: Webcamtoy; MEPPws: MEPP-website; Gray shaded cells: patients who used MEPP-website first; White cells: patients who used WCT first; **Δ** scores: the difference between the WTC's score and the MEPP's score for each category of the MeCUE questionnaire; Wilcoxon results= V. alpha = 0,05;

Table 3. *Summary of clinicians' feedback on the MEPP and WCT website to the following questions: "What did you prefer while using (MEPP/WCT)-website? What could have been better in (MEPP/WCT)-website?"*

Websites	Advantages	Disavantages
MEPPws	• Feature to assess compliance is good • Clear instructions • Easy to use	• Need auditive output • Central axis is problematic • Emailed info for use should be added • Instructions are non-optimal • User-friendliness to be improved
WCT	• Good accessibility (i.e. mobiles devices) • Easy to use	• Central axis is problematic • Instructions are non-optimal • Unsuited for therapeutic goals • User-friendliness to be improved

Legend : WCT: Webcamtoy; MEPPws: MEPP-website;

Figure Captions

Figure 1. Design of the study
Figure 1 Alt Text short description: Boxes and arrows that illustrate the study flow for patients and clinicians.
Figure 1 Alt Text long description: A graphic to illustrate study flow. Above, patients divided into two groups with ABBA design for the websites' trial. Each trial is followed by one assessment and one analyses timepoint. Below, clinicians who underwent a training to use the websites. The training is followed by a trial of the websites, an assessment and an analysis.

Legend: WCT: Webcamtoy; MEPPws: MEPP-website.

Figure 2. Example of the facial mirroring system for Webcamtoy (A) and MEPP-website (B).
Figure 2 Alt Text: A) A smiling person whose face is symmetrical through Webcam Toy's interface. B) The MEPP- website interface. On the left image, facial exercises' instructions on the center with a green button at the bottom to continue training. On the right image, a person whose face is symmetrical through MEPP-website' interface.

Figure 3. Patients (A) and clinicians (B) results to the modified MeCUE questionnaire for usefulness, intention to use and overall evaluation for both websites". The box plots are the first and third quartiles, the whiskers are the maximum and minimum non-remote values, the dots are extreme values and the red crosses are the means
Figure 3 Alt Text: Three box plots illustrating patients' ratings of both websites and three box plots illustrating clinicians' ratings of both websites. Preference toward MEPP-website in all instances.
Legend: MEPPws: MEPP-website.

Supplementary Materials

Supplementary Material 1

Table S1. *Appreciation of the WCT and MEPP-website by the patients and clinicians for each analyzed category of the MeCUE questionnaire. Appreciation of the WCT and MEPP (n=15)*

		WCT					MEPPws				
First website used	**Patients**	**Average Usefulness**	**Average Usability**	**Average loyalty**	**Average Intention**	**Overall**	**Average Usefulness**	**Average Usability**	**Average loyalty**	**Average Intention**	**Overall 2**
MEPP	**P6**	6	7	2.67	3.23	2	6.67	7	5.33	4.67	4
MEPP	**P7**	6	6.67	3.67	3.33	4	6	6	4.67	3.67	5
MEPP	**P8**	7	7	5	6	4	7	7	4.33	4	4
MEPP	**P9**	5.67	7	3	4.67	0	7	7	5.67	6.67	5
MEPP	**P10**	3	4	1.33	1	-3	7	7	5	6	4
MEPP	**P11**	6.67	6	2.67	3.67	3	6.33	6	4	5.67	4
WCT	**P2**	4.67	5.33	3.67	3.33	1.5	6.67	7	7	6.67	5
WCT	**P3**	6	6	3.33	3	5	7	7	7	6.67	5
WCT	**P4**	5.33	5	4.33	2.67	3	7	5.67	4.33	4	4.5
WCT	**P5**	5.33	4.67	5	3.33	3	7	7	4	3.67	4
	Clinicians										
	C1	5	7	1.33	3	2	6	7	5.67	5.33	4
	C2	4	6.33	3	3.67	2	6.33	5.33	6.67	6	4
	C3	4.33	5.33	3	4.33	2	6.67	6.33	6	6	3.8
	C4	4.33	5.33	2	4.33	2	6.33	3.67	5.33	5.33	4.5
	C5	3	5.67	3	3	-1	5.67	3.67	3.33	4.67	2.5

Legend: WCT: Webcamtoy; MEPPws: MEPP-website; Usefulness, usability, product loyalty and intention to use subscales are score on a scale of 1 to 7; 1= strongly disagree with the statement, 7= strongly agree with the statement. Overall evaluation scale goes from -5 to 5; -5= bad experience using the website, 5= good global attractiveness to the website;

Table S1.2. Median and interquartile range for inter-subject comparisons of a potential order effect

Order effect comparisons depending on webtool	Mdn (IQR) Usefulness	Mdn (IQR) Usability	Mdn (IQR) Loyalty	Mdn (IQR) Intention to use	Mdn (IQR) Overall
Patients					
MEPP first	6.835 (0.585)	7 (0.75)	4.835 (0.8325)	5.17 (1.75)	4 (0.75)
MEPP second	7 (0.0825)	7 (0.3325)	5.665 (2.7525)	5.335 (2.7525)	4.75 (0.625)
WCT first	5.33 (0.3325)	5.165 (0.58)	4 (0.9125)	3.5 (1.165)	3 (0.875)
WCT second	6 (0.75)	6.835 (0.8325)	2.835 (0.8325)	3.165 (0.4125)	2.5 (3.25)
Clinicians					
MEPP	6.33 (0.33)	5.33 (2.66)	5.67 (0.67)	5.33 (0.67)	4 (0.2)
WCT	4.33 (0.33)	5.67 (1)	3 (1)	3.67 (1.33)	2 (0)

Legend: WCT: Webcamtoy; MEPPws: MEPP-website; Mdn (IQR): median (interquartile range);

Supplementary Material 2

Table S2. *Number of completed sessions with MEPP-website during the first 14 days of therapy with Mann-Whitney*

Patients	**Severity of BP at onset (FNGS 2.0)**	**Mepp-website first**	**Number of completed sessions with MEPP-website during the first 14 days**														**Total of completed sessions (on a recommended total of 28)**	**Mdn (IQR)**
			D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14		
P2	4	N	1	0	1	0	0	0	1	1	1	1	0	0	1	0	7	6.5 (2.75)
P3	6	N	2	1	1	0	0	1	0	1	1	1	0	0	1	1	10	
P4	5	N	1	0	1	0	0	0	1	1	0	1	0	1	0	0	6	
P5	4	N	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	
P6	5	Y	1	2	1	2	2	2	2	2	2	2	2	2	2	2	26	26 (17.25)
P7	5	Y	1	2	1	2	2	2	2	2	2	2	2	2	2	2	26	
P8	4	Y	1	1	0	1	0	0	0	0	0	0	0	0	0	0	3	
P9	5	Y	1	2	1	0	0	1	0	0	0	0	0	0	0	0	5	
P10	5	Y	2	2	2	2	1	3	2	2	2	2	2	2	2	2	28	
P11	5	Y	1	2	2	1	2	3	3	3	3	2	2	1	2	2	29	

Legend: Mann-Whitney results= U; alpha = 0,05; N= No; Y = Yes; Mdn (IQR): median (interquartile range)

Supplementary Material 3

Table S3. *Summary of clinicians' feedback on the MEPP and WCT website to the following questions: "What did you prefer while using (MEPP/WCT)-website? What could have been better in (MEPP/WCT)-website?"*

Website	Clinician	Observation	Summarized information
MEPPws	C1	Easy to use and the instructions are easy to understand by the patient.	Clear instructions
	C1	It could be nice for the clinician to select also an auditive output for instructions.	Need auditive output
	C1	It is hard for patients to maintain their heads stable at the central axis while doing the exercises.	Central axis is problematic
	C2	The fact that you can follow your patient's compliance to the therapy is helpful to initiate dialog about how well-suited the therapy is for him.	Feature for compliance is good
	C2	It could be great if the patient could receive some information about his therapy by email (e.g., date to start, password, etc.)	Emailed info should be added
	C3	The instructions are written with a good font and are not too complex.	Clear instructions
	C3	It is hard for patients to maintain their heads stable at the central axis while doing the exercises.	Central axis is problematic
	C3	However, instructions could be shorter and centered on the page for clients who suffer from hemineglect.	Instructions non-optimal
	C4	It is really simple to choose exercises and to create a therapy profile. It is easy to add new exercises.	Easy to use
	C4	It could be great to have an overview of patient's session without having to leave the therapist interface (for authentication).	User-friendliness to be improved
	C4	It is hard for patients to maintain their heads stable at the central axis while doing the exercises.	Central axis is problematic
	C5	The instructions written in white color were easy to read.	Clear instructions
	C5	The navigation is not intuitive. However, the MEPP-website seems useful to me and more complete than the WCT.	User-friendliness to be improved
WCT	C1	It can be use on mobile devices, which is a great advantage for accessibility.	Good accessibility
	C1	It is hard for patients to maintain their heads stable at the central axis while doing the exercises.	Central axis is problematic
	C1	Patients are more likely to forget some instructions, above all if they don't bring their complementary sheet along.	Instructions non-optimal
	C2	The WCT website is easy to use	Easy to use
	C2	The WCT website isn't precise enough to allow a good therapeutic monitoring.	Unsuited for therapeutic goals
	C3	The WCT website is easy to use	Easy to use
	C3	WCT website can be confusing for patients with cognitive impairment, given the multiple options of face filters.	Unsuited for therapeutic goals
	C4/C4	It achieves the basic goal of reduplicating the face, nothing more	Unsuited for therapeutic goals
	C4	It is not easy to modify the therapy or add new exercises compare with the MEPP.	User-friendliness to be improved
	C5	It is hard for patients to maintain their heads stable at the central axis while doing the exercises.	Central axis is problematic

Legend : WCT: Webcamtoy; MEPPws: MEPP-website; Dark shaded cells = clinicians' suggestions of improvements, Pale shaded cells = features appreciated by clinicians