Using a Wireless EEG Device to Evaluate E-health and E-learning Interventions

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ABSTRACT

Background. Measuring patients' and health professionals' engagement and other reactions to e-health and e-learning interventions remains a challenge for researchers.

Objective. The aim of this pilot study was to assess the feasibility and acceptability of using a wireless EEG device to measure affective (anxiety, enjoyment, relaxation) and cognitive (attention, engagement, interest) reactions of patients and healthcare professionals during e-health or e-learning interventions.

Methods. Using a wireless EEG device, we measured patients' (n = 6) and health professionals' (n = 7) reactions during a 10-minute session of an e-health or e-learning intervention. The following feasibility and acceptability indicators were assessed and compared for patients and healthcare professionals: number of eligible participants who consented to participate, reasons for refusal, time to install and calibrate the wireless EEG device, number of participants who completed the full ten-minute sessions, participants' comfort when wearing the device, signal quality, and number of observations obtained for each reaction. The wireless EEG readings were compared to participants' self-rating of their reactions.

Results. We obtained at least 75% of possible observations for attention, engagement, enjoyment, and interest. EEG scores were similar to self-reported scores, but they varied throughout the sessions, which gave information on participants' real-time reactions to the e-health/e-learning interventions. Results on the other indicators support the feasibility and acceptability of the wireless EEG device for both patients and professionals.

Discussion. Using the wireless EEG device was feasible and acceptable. Future studies must examine its use in other contexts of care and explore which components of the interventions affected participants' reactions by combining wireless EEG and eye-tracking.

Keywords: e-health, e-learning, engagement, pilot projects, electroencephalography.

Using a Wireless EEG Device to Evaluate E-health and E-learning Interventions

Physical inactivity, smoking, hypercaloric diet, and other unhealthy behaviors are priority targets for disease prevention and management (Leiter et al., 2011). To address these risk factors, patients must initiate changes in their behaviors and healthcare professionals must support those changes (Garvey, Arathuzik, Miller, & Ard, 2016; The Emerging Risk Factors Collaboration, 2015). Over the last decade, an increasing number of web-based e-health and e-learning interventions have been developed and tested for these purposes (Cook et al., 2008). For patients, e-health interventions provide a learning environment that can support behavior change (Wantland, Portillo, Holzemer, Slaughter, & McGhee, 2004). For healthcare professionals, e-learning can facilitate the acquisition of the knowledge and skills required to support patients in health behavior change (Cook et al., 2008).

However, recent studies have shown that the effectiveness of e-health and e-learning interventions is limited by dropout rates of 50% to 80% (Cugelman, Thelwall, & Dawes, 2011; Krebs, Prochaska, & Rossi, 2010; Norman et al., 2007). A possible explanation for these numbers resides in the lack of user engagement, which is essential to sustain user participation and to achieve positive outcomes (Perski, Blandford, West, & Michie, 2017). Engagement can be divided into a behavioral and a psychological component (Colvin Clark & Mayer, 2016). Behavioral engagement is reflected in users' overt actions during the interventions—clicking, writing, or ticking boxes, for instances. Psychological engagement, on the other hand, is reflected in users' mental activity towards the learning goals, making it a more difficult construct to measure. Both forms of engagement are closely linked with other affective and cognitive reactions involved in learning, including attention, interest, enjoyment, relaxation and anxiety.

Thus, evaluating user engagement and other affective and cognitive reactions in e-health and e-learning interventions is a top research priority (Michie, Yardley, West, Patrick, & Greaves, 2017). Among the existing measurement methods, electroencephalography (EEG) allows for real-time assessment of electrical signals in various parts of the brain. It can detect patterns of mental activity associated with affective and cognitive reactions, including engagement (Li & Lu, 2009; Mampusti et al., 2011; Murugappan et al., 2008). However, EEG devices require users to wear dozens of electrodes while remaining completely still during the test, not to mention the specialized training required to interpret the results (Acharya, Hani, Cheek, Thirumala, & Tsuchida, 2016). Beside EEG devices, other methods are more commonly used to evaluate affective and cognitive reactions after online interventions. These methods involve users' self-rating of their reactions on visual analog scales (VAS), but do not provide real-time assessments during the interventions (Funke & Reips, 2012; Kuhlmann, Reips, Wienert, & Lippke, 2016; Reips & Funke, 2008).

In response to these challenges, wireless EEG devices have been developed. Although they cannot be substituted to full-scale EEG for diagnostic purposes, these devices are cheaper and use less electrodes, which reduces the time required for installation and allows users to move during measurement. The devices come with interpretation software products that compute real-time scores for different affective and cognitive reactions. Up to now, wireless EEGs' tracings have been compared to full-scale EEGs and their validity was supported (Badcock et al., 2015), but the validity of the software interpretations remains to be scrutinized. Nevertheless, wireless EEG devices are a promising and practical method to measure users' real-time reactions that could be

used to evaluate e-health or e-learning interventions. Accordingly, the aim of this pilot study was to assess the feasibility and acceptability of using a wireless EEG device to measure affective and cognitive reactions of patients and healthcare professionals during e-health or e-learning interventions.

METHOD

This prospective pilot study was conducted between April and May 2017 in a Canadian cardiology hospital. The study was approved by the institutional review board (#2017-2134) and registered at the ISRCTN registry (https://www.isrctn.com; ISRCTN12825237).

Participants

Based on anticipated recruitment rate, we aimed to approach 20 eligible participants over two months. Eligible participants were either patients expecting discharge from a coronary care unit or professionals from the same setting. Written consent was obtained from all participants.

Study procedure

Upon enrollment, participants completed a sociodemographic questionnaire, including age, gender, and education. A research assistant then installed and calibrated a wireless EEG device on their head. Participants were instructed to start the first session of an e-health or e-learning intervention on a laptop computer. Patients completed the procedure in their hospital room and healthcare professionals completed it in a closed office during a work shift. These conditions reflected the course of events on the unit. There was a possibility that participants could be interrupted to receive or provide regular care at any time during the sessions. If they had not been interrupted after ten minutes, the research assistant ended the experiment and asked participants to complete a questionnaire about their reactions to the intervention.

E-health and e-learning interventions

Two interventions were used, one for patients and one for healthcare professionals. Patients navigated through the first session of TAVIE@COEUR (Cossette et al., 2017), an e-health intervention to promote adherence to cardiovascular medication. Professionals viewed the first session of MOTIV@COEUR (Fontaine et al., 2016), an e-learning intervention on motivational interviewing. A typical timeline of the first 10 minutes of each intervention with actions assumed to promote behavioral engagement (i.e. clicks and questions) is presented in Figure 1. In both online interventions, participants navigated through videos of a nurse providing topic-relevant explanations (“N” in Figure 1). They had to click on “continue” buttons to move from one video to the next.

Patients watched videos of a nurse addressing the importance of taking cardiovascular medication as prescribed (3 x 1 min) and on behaviors related to medication (3 x 1 min). They also viewed a video of a patient sharing his experience with cardiovascular medication (2.5 min). On two occasions, they had to answer Yes/No questions; they also had to complete a questionnaire on drugs they were taking at home (“Q” in Figure 1) and they were presented with a short text on these drugs (“T” in Figure 1).

In the first video watched by healthcare professionals (2 min), a nurse introduced brief motivational interviewing and the learning objectives for MOTIV@COEUR. In the second video (11 min), the nurse presented the theoretical basis of motivational interviewing. On three occasions, videos showed text to emphasize the nurse's explanations ("T" in Figure 1).

Data collection

Emotive and cognitive reactions. Participants' reactions were measured with a wireless EEG device and VAS. The EPOC+© wireless EEG device (Figure 2) from EMOTIV (San-Francisco, CA) was used. The EPOC+© uses 14 electrodes that are positioned per the 10-20 international positioning system for EEGs (Acharya et al., 2016). The device's interpretation software (MyEmotiv©) computes real-time scores for six affective and cognitive reactions: anxiety, attention, engagement, enjoyment, interest, and relaxation. Scores range from 0 to 100, with higher scores indicating higher-intensity reactions.

During the sessions, participants' scores were recorded every minute for each of the six reactions. Therefore, a total of 60 scores per participant (10 scores * 6 reactions) was expected. Of note, the software requires a sufficient signal quality to compute the reactions, some reactions requiring a higher signal quality than others. Accordingly, it was possible that the software would not provide scores for some reactions if the signal quality was not sufficient. Since there was no previous report of the number of scores to expect, we estimated that obtaining 75% of possible scores was acceptable.

Immediately after the session, participants rated the degree to which they experienced the six affective and cognitive reactions measured by the wireless EEG device by tracing an X on a ten-centimeter VAS. The distance from the beginning of the VAS to the X was measured and transformed into a 0-100 score (e.g. 67mm = 67 points).

Feasibility and acceptability of the procedure. Indicators drawn from the literature on pilot studies (Feeley & Cossette, 2016) were assessed and compared for patients and healthcare professionals: number of eligible participants who consented to participate, reasons for refusal, time to install and calibrate the wireless EEG device, number of participants who completed the full ten-minute sessions, participants' comfort when wearing the device, signal quality, and number of observations obtained for each reaction. A VAS was also used to measure participants' comfort while wearing the wireless EEG device.

Analysis

Data were summarized with descriptive statistics, including frequency, percentage, mean and standard deviation (or median and minimum/maximum value if normality of the distribution was not achieved). Since the sample size was small, groups were compared on the basis of visual inspection.

Although the validity and reliability of the software interpretation was beyond the scope of this pilot study, the participants' scores on the reactions for which we obtained at least 75% of possible observations were graphed. The curves from the graphed scores were compared to participants' self-rating of their reactions during the intervention. A search for differences in

trends among patients' and professionals' scores was performed; as they had been exposed to different interventions, different trends were expected.

RESULTS

During the study period, 18 eligible participants (10 patients, eight professionals) were approached. Of those, 13 were recruited and enrolled (six patients and seven professionals). The recruitment rates were high at 60% for patients and 87.5% for professionals. Reasons for refusal included being too tired or not interested. On average, patients were 58 years old (range: 53-65); healthcare professionals were 36 years old (range: 26-54). Patients identified mostly as male (*n*=4, 67%) and half had completed a college education (n=3, 50%). Healthcare professionals identified mostly as female (n=4, 57%), were all nurses, and all had completed a university degree (n=7, 100%).

Feasibility and acceptability results are reported in Table 1. For both groups, the median time to install and calibrate the wireless EEG device was shorter or equal to other reports (2-5 min; Harrison, 2013); it took longer to install the device on patients than on professionals. All participants completed at least seven minutes of the sessions. Approximately half of the patients (n=3/6, 50%) and the professionals (n=4/7, 57%) completed the full 10-minute sessions. Patients were interrupted mostly because a healthcare professional walked into their room; healthcare professionals were interrupted because one of their assigned patients required care.

Comfort scores were generally high and similar for both groups. Comfort scores for participants who did (Median [Mdn] = 8.7) and did not (Mdn = 7.9) complete the sessions were also similar. Nevertheless, visual inspection of the comfort scores revealed that patients and professionals who did not complete the sessions reported higher comfort scores. Thus, it appeared that participants ended the sessions because of contextual factors and not because of uncomfortableness with the wireless EEG device. However, healthcare professionals who completed the sessions reported slightly lower comfort scores than those who did not. This could mean that wearing the wireless EEG device for a longer period increases discomfort. Signal quality was generally high throughout the sessions. We were unable to obtain any observations from one healthcare professional, even if the signal quality was moderate at 85% during the experiment. This participant was removed from the subsequent parts of the analysis.

In the protocol, we planned to calculate the number of observations obtained over 10 minutes. Half of participants stopped the sessions after seven minutes. Therefore, the majority of missing observations in the last three minutes of the experiment were due to interruption of the procedure and not to the wireless EEG device. Thus, the first seven minutes of the experiment were used for analyses. As shown in Table 1, at least 75% of possible observations for professionals' attention, engagement, enjoyment, and interest were obtained. This threshold was not reached for anxiety and relaxation. Results for patients were similar, except for enjoyment, which approached, but did not reach the 75% threshold. However, the threshold was reached with healthcare professionals and we decided to keep enjoyment for further analysis.

Affective and cognitive reactions are presented in Figure 3. Trends in patients' and professionals' scores on attention, engagement, enjoyment, and interest for the first seven minutes of the experiment were similar to the VAS scores measured after the experiment. On the

EEG and the VAS, professionals scored higher than patients. As expected, the wireless EEG scores varied throughout the sessions, providing real-time information on participants' reaction; this variation was not reflected in the single VAS measures obtained after the intervention. The difference in patients' and professionals' curves reflects that they were exposed to different interventions and suggests that the wireless EEG device provides a measure that was reactive to the interventions, which supports its potential.

CONCLUSIONS AND RECOMMENDATIONS

These results support the feasibility and the acceptability of using a wireless EEG device to evaluate e-health and e-learning interventions with hospitalised patients and healthcare professionals. Recruitment rates were high, installation and calibration of the device was feasible within a reasonable time, participants were comfortable, and the device yielded the expected number of observations for most reactions. Data obtained with the wireless EEG device are promising; they show variations in the intensity of reactions that are known to affect the outcomes of e-health and e-learning interventions. The strengths of this exploratory study include participants' blinding to their EEG scores and the absence of missing data for the VAS scores. Feasibility and acceptability were assessed in naturalistic clinical conditions, thereby increasing the applicability of the results to real-world settings and future nursing research. However, this is also a limit of the study: some sessions were interrupted by clinical events on the unit, resulting in missing EEG data. Although appropriate for a pilot study, the sample size was small and we only approached 18 out of the possible 20 participants because of administrative issues. It is also important to note that all participants in this study came from one setting and were clinically stable—patients were expecting discharge and professionals were assumed to be healthy.

Considering the strengths and limitations of this study, the results suggest that the use of wireless EEG device warrants further investigation. The next step would be to examine what components of the interventions affected participants' reactions. This could be achieved by combining wireless EEG and eye-tracking measurements with a larger sample of patients and professionals. Such studies could lead to adjustments of e-health and e-learning interventions to increase their effectiveness regarding behavior change and knowledge/skill acquisition. Plus, it appears relevant to test the wireless EEG device in other care settings and with patients who present with different clinical states.

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Table 1

Feasibility and Acceptability Results

	Patients *n*=6	**Professionals** *n*=7
Time to install and calibrate, *minutes* [1]	2.5 (1.0-10.0)	1.0 (1.0-4.0)
Completed the session, [2]	3 (50.0)	4 (57.1)
Comfort scores (0-10)[1]	8.7 (4.6-9.5)	7.7 (2.5-9.7)
Completed the session[1]	8.7 (7.9-9.4)	6.5 (2.9-9.7)
Did not complete the session[1]	8.8 (4.6-9.5)	7.7 (2.5-8.1)
Signal quality[1]	92 (55-100)	100 (85-100)
Observations **in the first 7 min**[2-3]	*n*=6	*n*=6
Anxiety	11 (26.2)	20 (47.6)
Attention	39 (92.3)	42 (100.0)
Engagement	37 (88.1)	36 (85.7)
Enjoyment	31 (73.8)	41 (97.6)
Interest	40 (95.2)	42 (100.0)
Relaxation	24 (57.1)	24 (57.1)

NOTE. [1] Median (minimum-maximum). [2] Frequency (%). [3] Results are presented for the first 7 minutes since approximately half of the participants did not complete an entire 10-minute session. There were 42 possible observations for both patients and professionals (7 minutes * 6 patients/professionals).

Figure 1. Typical timeline of the interventions

The MOTIV@Coeur timeline was used for patients and the TAVIE@Coeur timeline was used for professionals. Naviation through videos is identified with "N". Clicking on "continue" buttons to move from one video to the next is identified as "Click". Completing a questionnaire corresponds to "Q" and "Questionnaire", while reading a short text corresponds to "T".

Figure 2. EPOC+© wireless EEG device from Emotiv.

A person wearing the wireless EEG headset is shown navigating through the MOTIV@Coeur intervention.

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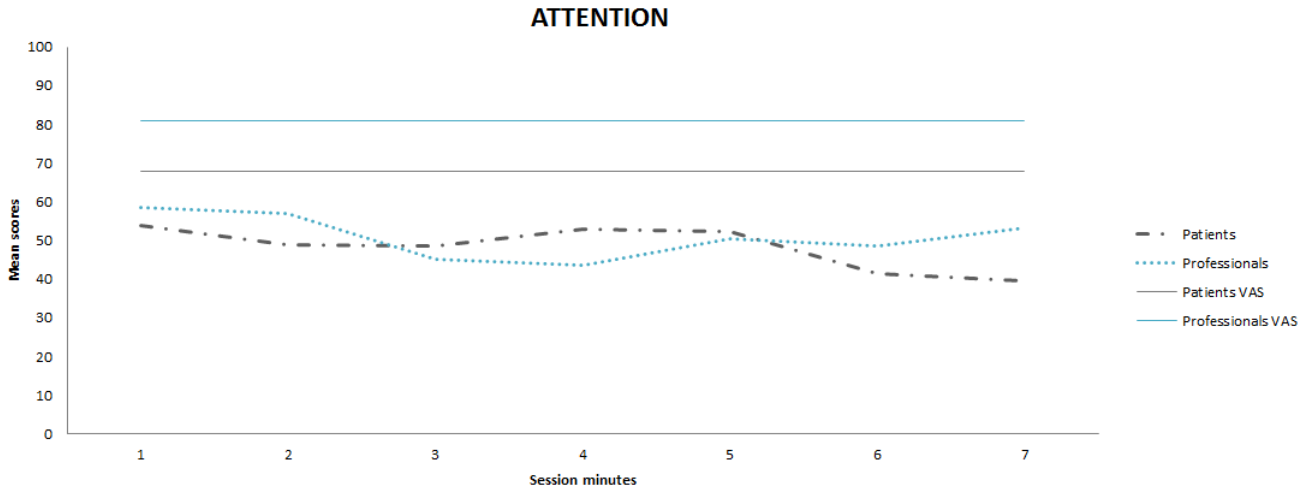

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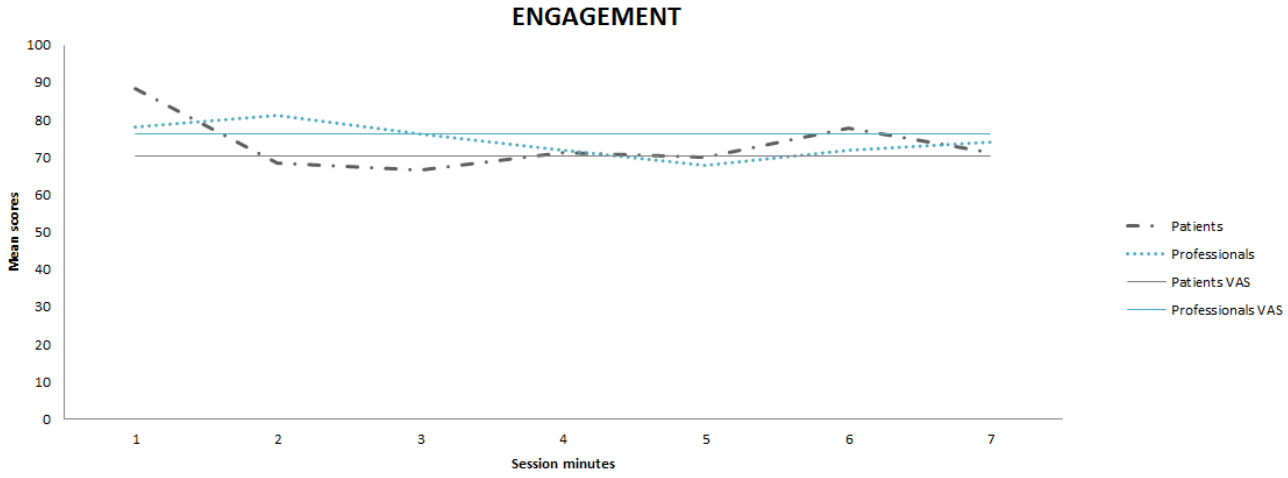

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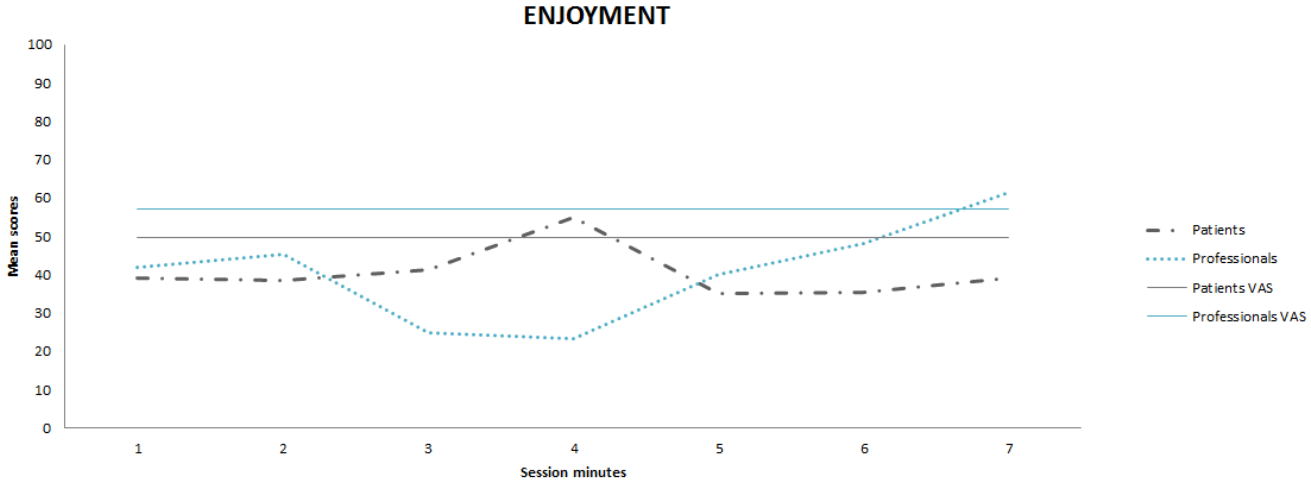

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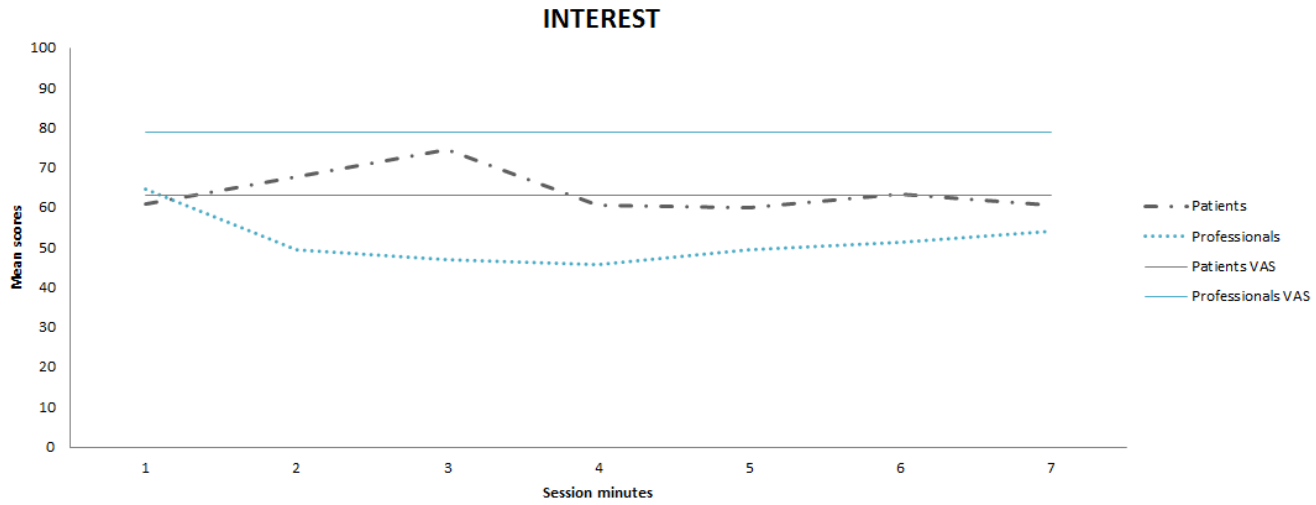

Figure 3. Descriptive results on attention, engagement, enjoyment and interest.

Curves representing scores obtaines with the wireless EEG device during the online interventions are represented as doted lines, while the VAS score obtained after the online interventions are represented as full lines. Scores for professionals are presented in bleue while patients are in black. For each reaction, results for professionals and patients are contrasted using means for each timepoint.