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ABSTRACT

The Canadian Armed Forces (CAF) considers the mental health and resiliency of its members a top priority. Leveraging technologies to create innovative approaches to mental health and resilience training may further optimize the well-being of military personnel. As one example of leveraging technologies in response to this CAF priority and in an effort to expand and modernize the Road to Mental Readiness (R2MR) mental health and resilience training program, the CAF designed and developed a mobile application (i.e., "app") – the R2MR app. The R2MR app is designed to provide on-the-go training to help manage stress responses, improve short-term performance and long-term mental health outcomes, as well as to promote treatment-seeking behaviours. The app is based on cognitive behavioural theory (CBT) and allows for repeated practice by the user. Six modules (e.g., self-talk, goal-setting) were developed to build CBT-based training scenarios to help users achieve mental health objectives. For instance, the mental health continuum model (MHCM) module enables users to self-monitor using a visual spectrum, accompanied by descriptors designed to correspond to four health anchors (i.e., healthy, reacting, injured, and ill). Further, a seventh module was added to the R2MR app on working memory to help users improve their fluid intelligence.

As part of the validation process, the R2MR app has gone through numerous studies to ensure usability, functionality and relevance. Specifically, the R2MR app has gone through an expert analytic assessment to ensure that the design abides by established interaction design principles and usability heuristics. Further usability studies have been conducted using the Concurrent Think Aloud (CTA) protocol, wherein participants verbalize their thoughts and behaviours while using the app, imparting insight to effectively tailor the app to different user demographics. In order to validate the content of the MHCM module of R2MR, an experiment was conducted to assess if the descriptors correspond with the visual spectrum and the anchors, as well as to validate portions of MHCM self-assessment. Our results indicate that further refinement to the phrasing of the descriptors could improve self-mapping consistency. We evaluated the benefits of arousal control training in various performance environments (e.g., marksmanship), using different populations (e.g., Military Police, civilians). This was done using the heart rate biofeedback and stress scales in the app. The results suggest the settings and instructions should be configured based on users' demographics and trade. Future directions and opportunities to further leverage technology in the space of mental health and resiliency will be discussed such as investigating training with the R2MR skills in a serious game with haptic feedback and biofeedback will evaluate engagement and performance under controlled and immersive stressors. Importantly, the R2MR app enables the use of advanced features of smartphones (e.g., gamification, biofeedback) to be leveraged as a testbed for collecting surveys, user feedback and usage analytics data. This will ultimately help increase our understanding of how to further promote mental health and resiliency of our military personnel.

1.0 INTRODUCTION

Maintaining the psychological health and resilience of military personnel is imperative for the Canadian Armed Forces (CAF), as it prepares personnel to adapt to, and overcome high-stress environments. Despite current best efforts, nearly one-fifth of CAF personnel are still impacted by mental illness [1] and a significant proportion of the CAF underutilize available mental health services [2]. Over the past few decades, the CAF has devoted many resources towards promoting the mental health and well-being of its members [1][3] and research provides some support for tailoring mental health training programs specifically to military personnel [4]. One approach to this, and a strategic priority of the CAF Surgeon General, is to leverage technology and innovate approaches as a method to promote patient engagement and access to care [5]. Recent technological advances in mobile (e.g., smartphones), wearable (e.g., heart rate monitors) and digitally-simulated immersive environments (DSIEs) (e.g., virtual reality, augmented reality, and 360-filming) provide an opportunity for the CAF to utilize DSIE technology in mental health training and clinical interventions to improve key outcomes. In order to successfully leverage technologies to improve upon mental health and well-being training programs and services, time and effort are required to properly design, develop and validate its use. This paper will review the key components used to ensure that the R2MR application meets its main objectives and enhances the in-classroom component of the R2MR training, while abiding by human-centred design principles.

1.1 Background

The current mental health and resiliency training employed by the CAF is the Road to Mental Readiness (R2MR) training program. Established in 2008, the R2MR curriculum was developed as a classroom-based training program that provides resilience training for members and their families across their career and deployment cycle, with some elements of the program based on the skills used in the US Navy Seals training program [6]. R2MR is skill-focused and requires a practical application, which has been tailored to interventions for rank, occupation, environment, and tasks.

As outlined in [7], the R2MR curriculum consists of six mental health management skills based on cognitive behavioural theory (CBT). Four are skills (goal setting, self-talk, visualization, and tactical breathing) that are intended to assist individuals in managing physiological responses to stress and enhance their performance. The two remaining skills, attentional control and psychological self-monitoring, were included in the curriculum based on feedback from CAF personnel implementing the original R2MR curriculum. Attention control is intended to direct individuals' attention to specific cues during a task while discounting irrelevant stimuli. The final component, psychological self-monitoring is based on the Mental Health Continuum Model (MHCM), which was developed in collaboration with the US Marine Corps. The MHCM is used to promote skills associated with identifying symptoms of psychological distress in oneself and others (see [7] for more details).

1.2 Development of the R2MR Mobile Application

It has been demonstrated that repetitive application and practice of skills in the training environment is essential for retention and effectiveness [8]. As such, in an effort to expand the R2MR training, the CAF designed and developed a mobile application (i.e., "app"). The R2MR app (Figure 1) is intended to provide on-the-go training to help manage stress responses, improve short-term performance and long-term mental health outcomes, as well as to promote treatment-seeking behaviours (see [7] for details). The main objectives of the R2MR app are (1) to complement the current R2MR training, (2) to turn R2MR skills into life skills and to individualize R2MR skills, and (3) to provide access to additional resources for further care.

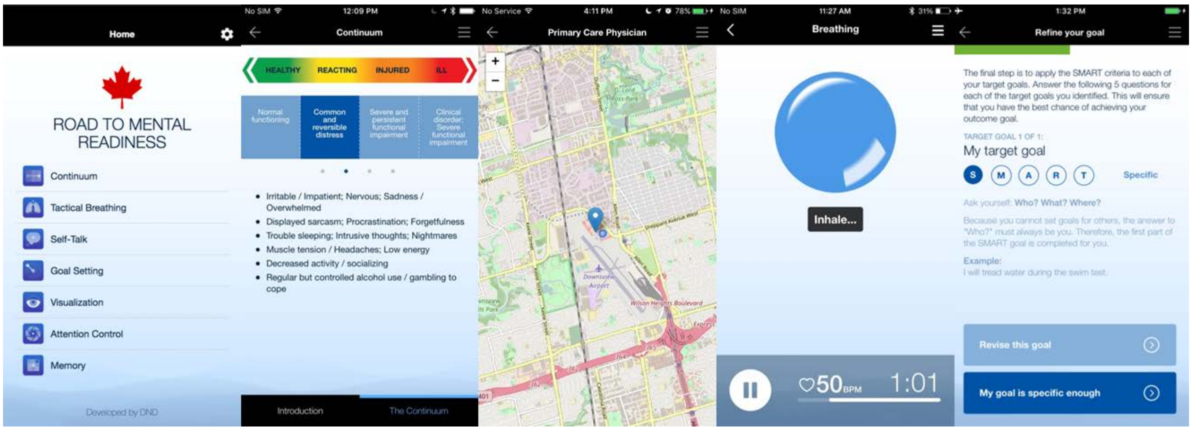

Figure 1. Example screenshots of the R2MR app.

As a complement and expansion of the curriculum, the R2MR app provides training and exercises that are included in the six classroom-based training sessions as well as an additional module on working memory [9]:

1. **Goal Setting:** Interactive tool for applying the SMART (Specific, Measurable, Achievable, Relevant, Time-bound) criteria in order to achieve desired goals. This module is integrated into calendar reminders and tracks the users' progress over time.

2. **Self-talk:** Interactive guide intended to direct the users to reframe and challenge their negative self-talk and to replace it with positive statements as well as to bookmark positive accomplishments. This module is integrated with notifications and self-monitoring.

3. **Visualization:** Guided training to help users develop customized scripts for effective mental imagery. This module is integrated with recording and playback functionality.

4. **Tactical Breathing:** Interactive breathing guide for controlled diaphragmic breathing for optimal arousal control. This module is available with near real-time heart rate biofeedback.

5. **Attention Control:** Training tool designed to enhance focused and selective attention, as well as the ability to shift attention when required. This module includes gamification and is adapted to the users' performance level.

6. **MHCM:** Self-monitoring tool to keep track of users' mood, attitude and performance, sleep, physical symptoms, social behaviour, as well as alcohol and gambling use. This module provides customized suggested resources for care.

7. **Memory:** Training tool designed to enhance working memory and fluid intelligence. This module includes gamification and is adapted to the users' performance level.

1.2.1 Leveraging the Advanced Features of the Smartphone within the R2MR App

The R2MR app offers the opportunity of individualized training and functions with and without an online connection. By harnessing the advanced features of the smartphone, the R2MR app offers users the ability to track their progress over time as well set up calendar notifications in order to reinforce rehearsal of the resilience and executive functioning skills taught in the app in order to achieve desired goals. The R2MR app also contains multimedia and graphics, such as audio recordings and playback, in order to enhance user experience. In addition, offline access to local database storage within the smartphone allows for users to access information in the palm of their hands whenever they need it, even if no internet connection is available. Further, by connecting to location-based direct dialling, users have access to care directly within the R2MR app.

The advancement and availability of off-the-shelf wearable technologies such as heart rate monitors offer the opportunity to explore the effectiveness of wearable sensors as a complement to mobile learning. These can be leveraged in the R2MR app. Biofeedback from wearable devices (e.g., heart rate monitors) can inform the user of the physiological benefits of using the app. Commercial wearable monitors are not certified for monitoring physiological data to medical standards, but they have been shown to be adequately reliable in most use-cases relevant to the R2MR apps (i.e., while the user is relatively stationary) [10]. More specifically, one of the modules of the R2MR app, Tactical Breathing, guides the user through deep, diaphragmatic breathing. The module can connect to wearable sensors and display the user's heart rate during the breathing exercise. Heart rate biofeedback has been previously shown to be a useful complement to similar tactical breathing training during military-relevant immersive simulations (i.e., virtual reality (VR)) in CAF soldiers to attain an optimal heart rate and arousal state for improved stress management skills [8]. It has been shown that achieving an optimal heart rate during a task is a crucial component for improving performance [11] as well as for improving mental health and resiliency [12].

1.3 Current Research

The design and development of the R2MR app has been a collaborative process, combining efforts from researchers, in-house developers, contractors, and the R2MR curriculum developers. In order to find the unique balance of achieving the desired outcomes from the curriculum developers and end-users, we have gone through an iterative and agile design and development process. Further, as part of the validation process and to ensure an optimal balance between human-centred design and valid content, we have conducted a preliminary series of qualitative and quantitative studies. The studies include (1) expert analysis, (2) an evaluation of the usability, performance, and utility of the R2MR app, (3) validation of the content within the MHCM, and (4) assessment of the role of heart rate biofeedback within the Tactical Breathing module.

The work summarized below has been conducted under DRDC Toronto's Human Research Ethics Committee's approval and guidelines. Some aspects of the design, development, and evaluation have been conducted in collaboration with allies, industry, and academia.

2.0 THE R2MR MOBILE APP DESIGN PROCESS

The design process of the R2MR app has evolved from concept (simple wireframe designs) to deployment through an iterative design process. Here we highlight how we have modelled the design process off of industry standards. As part of the design process and in order to achieve ideal human-centred design and to optimize user interface and user experience (UI/UX), we also conducted a preliminary online design competition and ran a series of usability studies on both civilian and CAF members.

2.1 User-Interface/User Experience Expert Analysis

After selecting a designer from an online design competition, we designed each R2MR module to have a neutral common look and feel (see Figure 2) that could represent all Canadians, not just CAF members. As part of the design process and in order to optimize a user-friendly design (i.e., UI/UX), we solicited expert review on one of the preliminary versions of the R2MR modules along with recommendations on how to improve its UI/UX.

2.1.1 Methods

We received expert design analysis from an impartial third-party contractor assessing the UI/UX of the modules within R2MR app (see [13]) and recommendations on other available resilience apps to model off of (see [14]). The analytic assessment included a rating of the app's various features and components against established interaction design principles [15], usability heuristics [16], and mobile design guidelines [17], as informed by the consultants' previous experience and research on medical training apps.

2.1.2 Results

The outcome of the expert analysis provided feedback on the UI/UX of the R2MR app and recommendations on improving the app's design. The overall recommendations are provided in detail in [13]. In summary, the following recommendations were reported by [13] including:

1. Combine all app modules into one training suite.
2. Display all tools on the home screen for accessibility to all exercises.
3. Simplify navigation and combine functionality.
4. Create user profiles for personalization, with the intention to have a greater understanding of the target audience.
5. Anonymize the database.
6. Contextualize experience by displaying information when relevant to the task.
7. Design for accessibility with meaningful icons and legible/visible fonts, buttons and colours.

Further, recommendations were provided by [14] on other available resilience apps. The authors identified effective components of other apps that the R2MR app could benefit from. Some examples included the suggestion to provide meaningful instructions for each exercise in context (similar to Australian Veterans Affairs' *High Res* app) and to consider a "Tap to Begin" function before the commencement of a breathing exercise (similar to T2 Health's *Virtual Hope Box* app).

2.2 Usability of the R2MR Mobile App

As part of the design process and in order to achieve ideal human-centred design and to optimize UI/UX, we also ran a series of usability studies on both civilian and CAF members. Usability data were collected in a series of exploratory usability studies during the design phase of the R2MR mobile app development. Exploratory usability studies were conducted to assess users' expectations, experience, performance, and satisfaction with the app, to identify specific usability problems and to evaluate access to the functionality of the system.

2.2.1 Methods

Participants were civilians (previously reported in [18]) or CAF members and were randomly assigned to one or more of the seven mobile applications modules and completed a one-on-one, open-ended interview session. The researcher asked participants a series of exploratory questions to understand and uncover how the users want to use the mobile app [19]. Participants also explored the R2MR modules using the Concurrent Think Aloud protocol (CTA), a commonly used paradigm in usability studies to understand participants' thoughts and elicit real-time feedback as they navigate through applications [20][21]. Participants also completed a generic usability scale, the System Usability Scale [22], and answered a series of specific questions about the functionality of each R2MR module. Lastly, user feedback (see Figure 2) and mobile usage analytics (e.g., number of clicks) were extracted to observe patterns of mobile app usage.

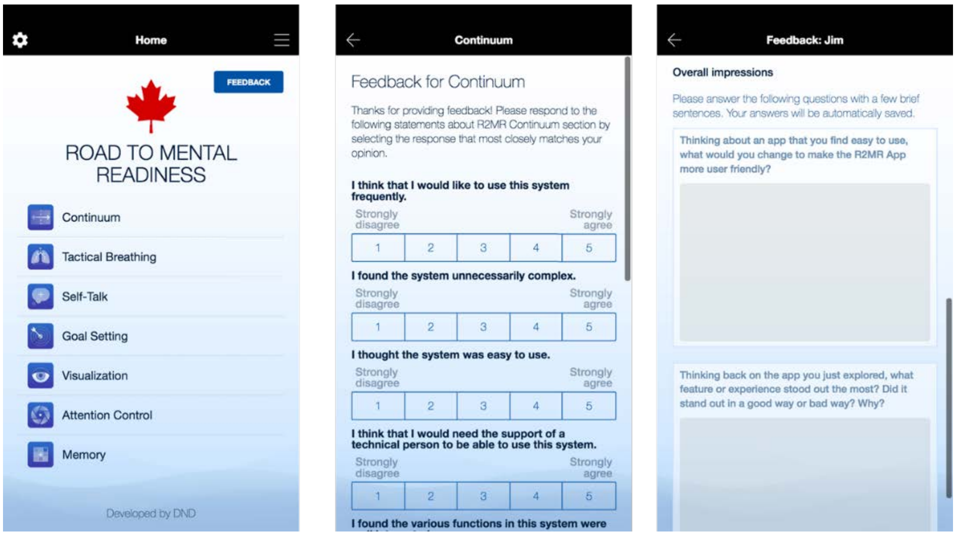

Figure 2. Screenshots of the user-feedback journey of the R2MR app.

2.2.2 Results

The qualitative results from the usability studies revealed overarching contrasting themes. CAF users (who have previously taken in-class R2MR curriculum) were more accepting of the different modules as prescribed training tools compared to civilian participants. In contrast, civilian participants enjoyed the customization of the app in order to enhance individual training. Further, the CAF members wanted to be able to view their progress in the app compared to others, whereas civilians were interested in seeing individual progress. Both populations expected to see output from the mobile app where input was given. For instance, both military and civilian participants expected to see the progression of their performance and to be able to track results for games and activities in the mobile app. Analytics of the participants' navigation (e.g., number of clicks, time spent on a function, etc.) were analyzed to assess if there were any patterns or "sticky navigation" (i.e., when user gets stuck on a function). Example data are presented in Figure 3. The datasets displayed in Figure 3 serve as an example of the type of data we can extract from consenting participants via an online server or extract locally during experimentation.

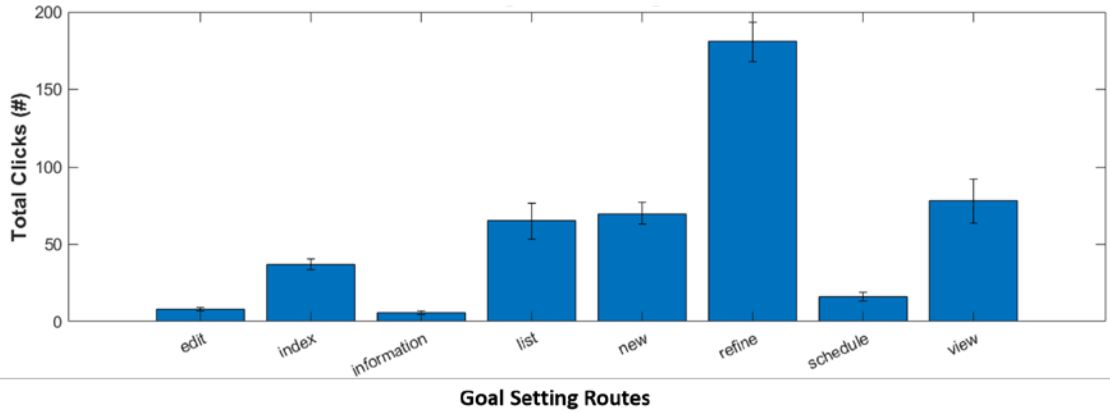

Figure 3. Example user analytics for the total number of clicks in the Goal Setting module separated by functions within the module by CAF members during usability testing. Error Bars denote standard error.

3.0 R2MR MOBILE APP DEVELOPMENT PROCESS

Similar to the design process, the mobile development process of the R2MR app has involved a combination of in-house development, contracting, and collaboration. The first requirement of the development process was the decision between "Waterfall" and "Agile" development models. The Waterfall Model provides a clear and definitive sequential plan for a project in which one stage must be fully completed before moving onto the next [23]. The Waterfall Model is ideal for projects with an established and extensive requirement analysis and a clear idea of what the final product should be [24]. In contrast, the Agile Model allows clients to provide feedback and alter features in the product at different stages of the life cycle [23]. The Agile Model requires strong and successful management to ensure that the requirements are being analyzed at different stages [24]. The Agile Model is preferred for projects that are dynamic and where the client does not have specific requirements for the final product [25]. For the development of the R2MR app, the agile development model was chosen to allow for a collaborative and iterative design and development process.

3.1 Hybrid versus Native Development

As a small team, we had to prioritize resources in the development process of the R2MR app. As the requirement for the R2MR app was to eventually make resilience training accessible to all Canadians, we needed to develop the app for both iOS and Android users. As such, we had to decide whether to develop two native apps or a web-based hybrid app. A native app is an app built for a specific platform and can be optimized for maximum performance with direct access to low-level hardware (e.g., microphone). The app can perform at faster speeds, has greater flexibility in customization, and is more responsive. The downfall is that it requires multiple codebases if the app needs to be built on multiple platforms [26]. A hybrid app, on the other hand, is a mixture between a native app and a web app (website), which has similar internal components to a website but can function like a native built app. Hybrid apps can be created with only one codebase but can be installed on multiple platforms (such as iOS, Android). The downside is that it will not be fully optimized for each platform it is built on, and will rely on external plug-ins to access low-level hardware; thus, typically, creating a poorer-performing app than a native app [26]. Since our requirements were to deploy the R2MR app on iTunes (for iOS) and Google Play (for Android) with limited resources, R2MR was developed as a hybrid app and deployed to both platforms (iOS: https://itunes.apple.com/ca/app/r2mr/id1148743063?mt=8; Android: https://play.google.com/store/apps/details?id=ca.drdc.rddc.r2mr&hl=en_CA).

3.1.1 Methods

Although our app was developed as a hybrid, as part of the evaluation process and in order to make direct comparisons, we also developed a native iOS app. We conducted a trial comparing the performance of one of the R2MR modules (Tactical Breathing; Figure 4), which requires graphics, multimedia and relies on an internal database, on both platforms (native iOS and hybrid). We evaluated the Tactical Breathing module on an iPhone 6 and compared the speed and processing power needed for each.

We used the "Instruments" app, a tool that comes with XCode (Apple Inc.) to collect and track the analytical data used in the trial. Within the trial, we monitored a variety of different properties including launch time, graphic requirements, memory, percentage of computer processing unit (CPU) usage and amount of "data reading" required. The trial consisted of initializing the Tactical Breathing module and completing an exercise with the default settings. The trial was deemed complete once the results section had been reached and the graph displayed results. It is worth noting that these results should only be used for comparison and not for a real projection of app use. This is because the extra analytics placed on the phone greatly diminishes its processing performance.

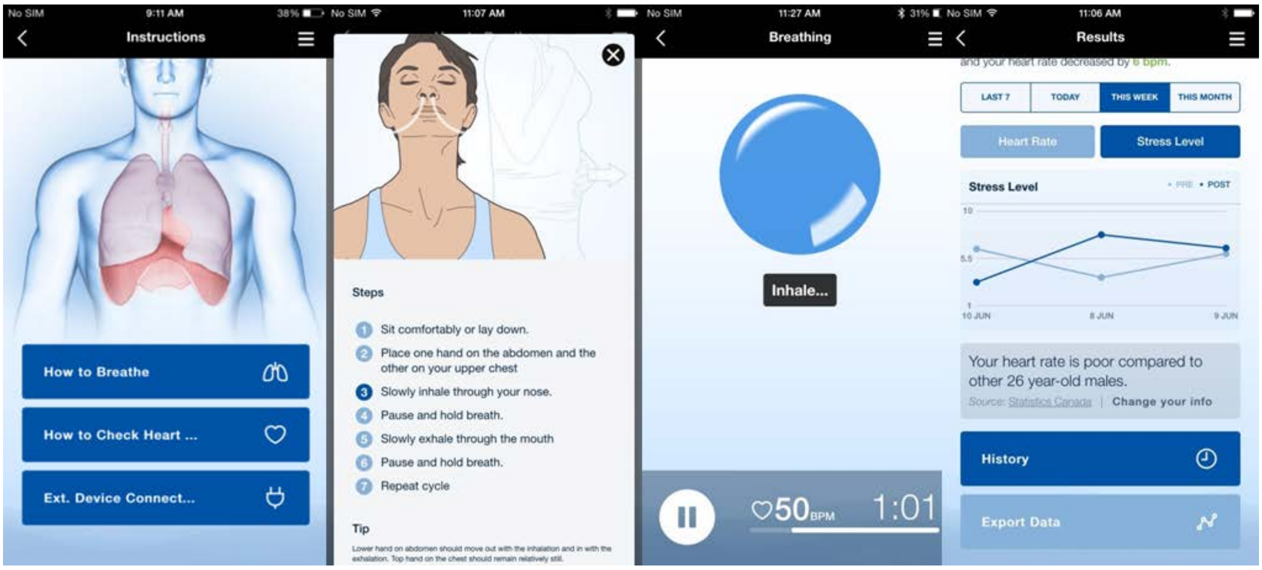

Figure 4. Screenshots of the Tactical Breathing module within the R2MR app.

3.1.2 Results

The hybrid versus native trial resulted in a number of performance differences between the two Tactical Breathing apps. Overall, the hybrid app took approximately three times longer to launch than the native app. Although simple transitions (e.g., changing page) were faster on the hybrid app, more complicated transitions and graphical operations (e.g., drawing and rendering objects) and data saving operations produced a greater lag. For details on performance metrics of an example trial, see Table 1.

Table 1. Performance metrics of the native vs. hybrid Tactical Breathing app.

Variable	Description	Native iOS Performance	Hybrid iOS Performance
Launch time (Seconds)	The time it takes for the app to load to the main screen when it is first opened.	4.88	15.93
Frames per second (FPS)	Average FPS of the first 20-sec interval of the trial.	25.08	11.78
Central Processing Unit (CPU) (Percentage)	Average amount of CPU usage that the app uses to start the tactical breathing exercise.	32.6	36.1
Heap Allocations (Mebibytes)	All temporary memory management (i.e., Virtual Memory) allocated as persistent bytes by the operating system.	8.13	17.09
Memory Used (Gibibytes)	Total memory used for the entire trial.	2.94	3.16
Data read (Gibibytes)	Total data acquired from the app for storage and processing within the Random Access Memory (RAM)	19.6	22.22

In summary, the native app performed faster than the hybrid app, especially for its initial launch. Since the hybrid app was required to read more data, it resulted in additional memory requirements and performance lags.

3.2 Content Validation

A critical component of the validation process of an educational mobile app is to ensure that the content is delivered with optimal fidelity to the instructional design of the curriculum and provides the appropriate information for the intended learning outcomes. One of the main components of the R2MR app is the MHCM. The MHCM is a self-monitoring tool that also provides access to care via the maps and dialling apps. In order to evaluate its content, an experiment was conducted to assess if the phrasing of the MHCM descriptors corresponds to validated measures assessing similar constructs and to the anchors (i.e., *healthy*, *reacting*, *injured*, *ill*) in the continuum (see [27]). This was done for each of the six functional domains (i.e., (i) Mood, (ii) Attitude & Performance, (iii) Sleep, (iv) Physical Symptoms, (v) Social Behaviour, (vi) Alcohol & Gambling) featured in the MHCM.

3.2.1 Methods

Participants (*N* = 392) were Regular Force CAF members and were randomly assigned to self-map onto the MHCM with the descriptors and anchors together (as is presented in the app) or separately in an online study. Participants also completed validated measures that assessed the same or similar constructs to those presented in the MHCM (e.g., alcohol use, depression/anxiety) (see [27] for complete details).

3.2.2 Results

Two main findings emerged in [27]. First, the results indicated support for the MHCM in its current form such that there was some alignment with how participants self-mapped onto the MHCM descriptors and their scores on the corresponding validated measures [27]. However, there was variation across the functional domains, suggesting some improvements can be made to the descriptors to improve upon users' ability to distinguish between symptom severity [27]. For instance, in some cases, participants self-mapped as *healthy* onto the MHCM Mood domain but screened positive for symptoms of psychological distress (i.e., depression and/or anxiety; see Figure 5 for example).

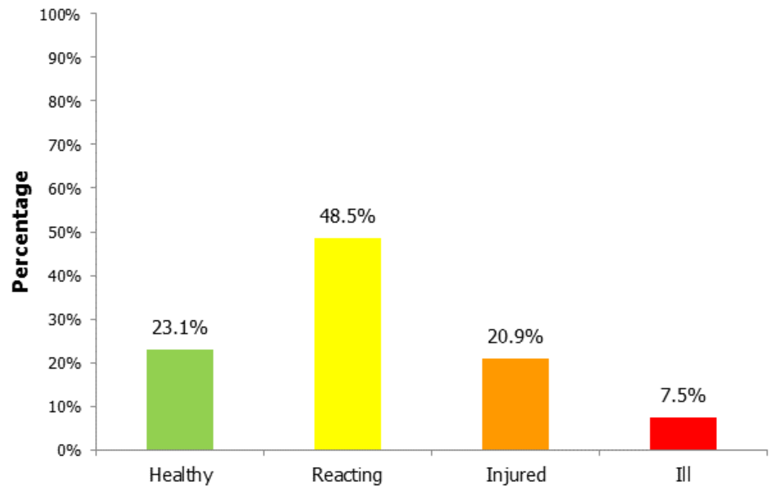

Figure 5. MHCM Mood anchor self-mapping among participants who screened positive for psychological distress (n = 138).

Second, although the rates varied across functional domains, at least 15% of participants were inconsistent in self-mapping onto the corresponding descriptor and anchor (see Table 2). In other words, in some cases participants self-mapped as healthy, reacting, injured, or ill on the continuum, but selected a descriptor that in the MHCM is matched to a different anchor than what was selected (see [27] for complete results).

Table 2: Percentage of participants with consistent descriptor and visual spectrum self-mapping.

Functional Domain	Unweighted *n*	Weighted %/*n*[a] (95% Confidence Interval)
Mood	257	68.1/27882 (61.2 to 74.2)*
Attitude & Performance	258	77.2/31914 (70.8 to 82.5)*
Sleep	259	54.7/22654 (47.7 to 61.4)
Physical Symptoms	257	62.4/25634 (55.6 to 68.7)*
Social Behaviour	257	68.0/27878 (61.2 to 74.1)*
Alcohol & Gambling	254	83.1/33725 (77.6 to 87.4)*

[a] Weighted cell counts were rounded to the nearest whole number.
*p value for $\chi^2 < .001$

3.3 Biofeedback and Arousal Control Evaluation

Another crucial component of the development process involved integrating the R2MR app with the advanced features (i.e., low-level hardware) of the smartphone. As discussed previously, one such example was the connections to wearable sensors via Bluetooth available within the Tactical Breathing module. Specifically, we have incorporated connection to wearable heart rate monitors to evaluate the impact of near real-time ("real-time") heart rate biofeedback on arousal control (see Figure 6). Available both pre/post and real-time, the heart rate biofeedback option during the breathing training/exercise offers users the ability to be objectively aware of their current physiological state. This is important as many individuals are poor at accurately perceiving their physiological state such as heart rate [28].

3.3.1 Methods

In a previously described study [7], we evaluated the effectiveness of different types of real-time biofeedback presented in a proprietary app provided by Hexoskin (Carré Technologies Inc.) while following an audio-recorded Tactical Breathing exercise. We tested Search and Rescue Technicians (SAR Techs) (n = 10) undergoing R2MR training to see if biofeedback could enhance the learning of tactical breathing. Specifically, participants listened to an audio recording of a script for tactical breathing and practiced three times per day for four days. Each session consisted of tactical breathing with and without real-time visual feedback of their physiological metrics (i.e., breathing and heart rates). The two types of visual feedback were (1) numbers representing breathing and heart rates, and (2) a visual animation depicting lungs with a graph trace of their heart rate. In addition, resting breathing and heart rates were also recorded prior to each experimental condition (i.e., baseline condition).

In a follow-up study on the Canadian Forces Military Police Academy (CFMPA) (see [29] for details), participants (n = 28) were instructed to train on their own time with the Tactical Breathing module within the R2MR app twice a day, five times a week for 12 weeks. Participants were divided into three groups: (1) control group: participants performed tactical breathing as instructed in the R2MR curriculum, (2) app only group: participants performed tactical breathing aided by the Tactical Breathing visual prompts, and (3) app plus biofeedback group: participants performed tactical breathing aided by the Tactical Breathing visual prompts and biofeedback from wearable sensors (Mio Alpha; Physical Enterprises Inc.).

3.3.2 Control Results

As previously reported in [7], participants successfully followed the breathing prompts and lowered their breathing rate compared to baseline ($F(2,127) = 59.7$, $p < 0.05$, see Figure 6). No differences in heart rate were observed ($F(3,171) = 2.2$, $p > 0.05$; see Figure 6B), however, between experimental conditions and baseline conditions, representing a floor effect at performing tactical breathing at rest without an external stressor.

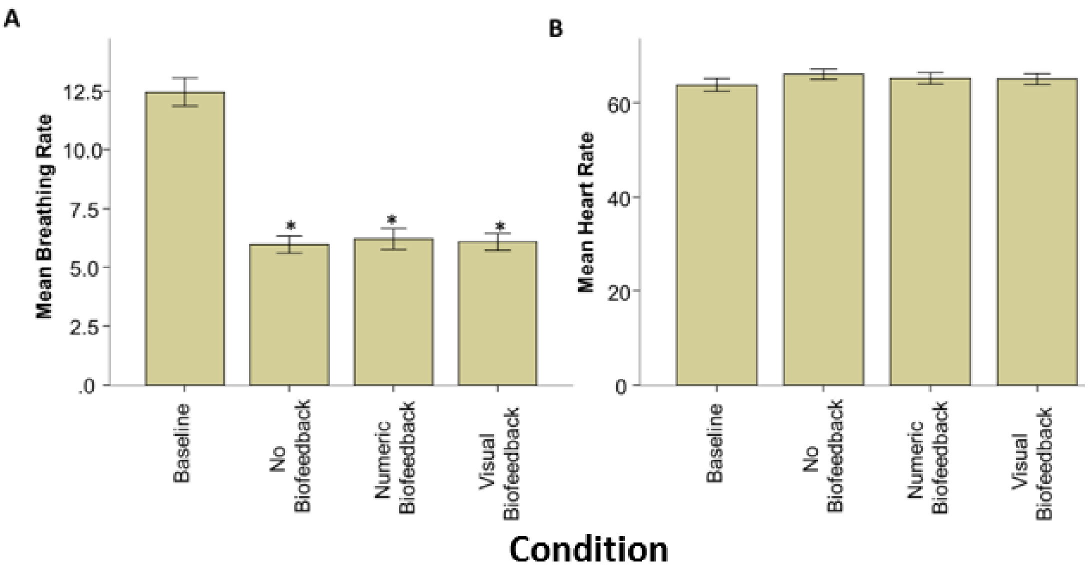

Figure 6. Mean Breathing Rate (A), Heart Rate (B) for the Baseline and Experimental Conditions During Tactical Breathing (from [7]); *Denotes p<0.05 (Bonferroni).

In a follow-up study on CFMPA personnel, no overall differences were observed across control or experimental groups. These differences could be due in part to poor compliance to the suggested training in the app plus biofeedback group (13% compliance) compared with compliance rates of the app only group (43%; p = 0.054) and control group (45%; $p < 0.05$). The participants reported difficulties finding time outside of the busy curriculum to perform the requested training. Pooled across participants and trials, there appears to be a dip in heart rate after one breathing cycle (i.e., 16 seconds) (see Figure 7).

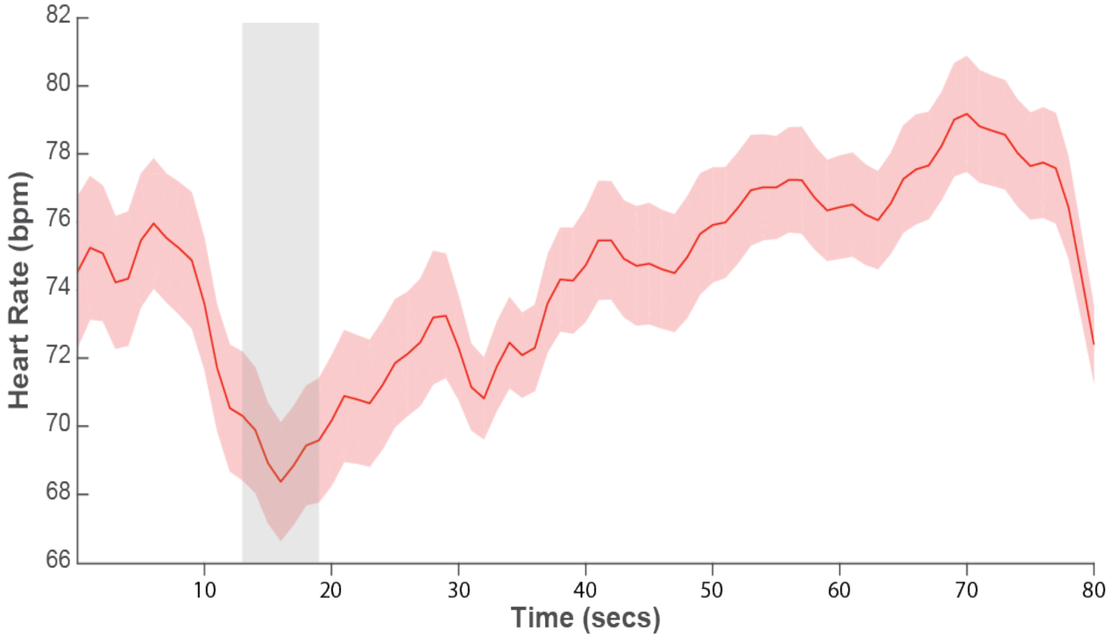

Figure 7. Heart Rate (beats per minute) biofeedback data (mean plus standard error of the mean; low-pass filtered at 0.5Hz) during Tactical Breathing session from app plus biofeedback group. Grey rectangle overlaps with one breathing cycle (i.e., 16 seconds) (from [29]).

In order to influence future compliance rates, the optimal number of breathing cycles required for optimal performance is being investigated in an ongoing collaboration with the University of Waterloo to decipher if one breathing cycle may be enough to impact arousal control and ultimately the performance of a given, high-pressure task (e.g., novice marksmanship).

4.0 DISCUSSION

In summary, the results presented in this paper reinforce the requirement for comprehensive evaluation during all stages of app development in order to create an effective mobile training app. Expert analyses of the preliminary R2MR modules reveal the requirement to combine the app into one training suite with a user login requirement for personalization and for tracking analytics. Usability findings indicate that participants may benefit from a more overt "so-what" factor for each module and for the app as a whole. The results indicate that participants were also left longing for more output from the app as some of the modules require a significant amount of user input. The usability results also suggest population differences. The CAF users were more accepting than the civilians of the app as a prescribed training tool delivered as an adjunct to the R2MR training curriculum. Further, the usability results indicate that training (e.g., instructions, examples, feedback) should be tailored to specific user types (e.g., trade, rank).

Our results from the validation of the MHCM indicate that modifications to the wording of some of the descriptors in the model could improve upon self-assessment consistency within the MHCM. In addition, in order to improve compliance rates in self-paced mobile learning, preliminary evidence from CFMPA participants suggests that in order to increase compliance to using training apps, integration within an ongoing classroom curriculum could be beneficial. As such, it is recommended to have top-down support in order to integrate mobile apps as part of the curriculum. Further, the biofeedback results indicate that arousal control training (e.g., using the Tactical Breathing module) should be performed under stressful, task-relevant situations in order to avoid floor/ceiling effects as per the SAR Techs and CFMPA members at rest. Further analyses are required to establish the relationship between arousal control (e.g., heart rate variability) and performance during stressful training or theatre of operations.

4.1 Ongoing and Future Research on R2MR App

Building upon the capabilities, findings and collaborations (allies, industry, and academia) resulting from work on the R2MR app and curriculum, we are currently looking to address the gaps in technological interventions for resilience training and therapy. As such, we will evaluate the effectiveness of current technologies on resilience training and therapy including physiological monitoring with wearable physiological sensors, immersive environments (e.g., virtual reality, and haptic vests), as well as remote access to healthcare professionals, while anonymously tracking usage analytics data and user feedback in order to tailor training and therapy to the given user.

4.1.1 Configuration for Collaboration

Mental health and well-being are also considered high priorities by paramilitary departments (e.g., first responders) and other military allies. As such, we have developed the R2MR app with localized language, graphics and media files for quick and easy configuration to other languages, cultures and trades. With a user-friendly Graphical User Interface (GUI), the R2MR app, coded in JavaScript (JS) in an Ember JS framework, can be configured relatively easily to accommodate translations and configured examples for different populations for training and in theatre.

As such, we have begun collaborative work with universities and allies from the New Zealand Defence Force (NZDF), Dutch Ministry of Defence (MoD) and Danish MoD, all with configured versions of the R2MR app (in various stages of development). In collaboration with the University of Waterloo, we are currently examining the effectiveness of app-based tactical breathing and “naturalistic” (i.e., available if required) biofeedback in novice civilian marksmanship. Expanding on the work with novice civilians and in collaboration with the NZDF, we are investigating the control of breathing and biofeedback on elite marksmanship during meaningful high-pressure (e.g., shooting competition) marksmanship environments. Further ongoing usability and experimental studies on configured versions of the R2MR app are currently in different stages of evaluation in collaboration with the NZDF, Danish MoD and Dutch MoD.

4.2 Ongoing and Future Research Building Upon R2MR App

4.2.1 R2MR Serious Game Development

The CAF is currently considering the expansion of the R2MR app into a serious game in order to allow training in simulated stressful CAF-relevant environments. Based on the gaming literature, it is clear that clinical games can be successful in teaching a desired skill or behaviour, but fail in engaging players over time as they lack a fun factor. This is because they are designed to teach a desired skill or behaviour, not to entertain the gamer. Moreover, clinical games are generally developed under significant time and cost constraints. Commercial video games are designed to entertain and engage the player and are successful in doing so as reports from 2018 indicate that 67% of Americans report playing video games [30]. However, clinical videogames aimed at addressing mental health issues such as anxiety fail to appeal to young men [31]. This supports the notion that young men are less likely to seek mental health help compared to young women [32]. Thus, leveraging commercial games' motivational characteristics to teach resilience is a plausible method to train resilience while engaging gamers.

Serious games have been shown to have promise for increasing the efficiency of training complex cognitive skills and improving performance; for instance, in one study training with serious games was shown to increase usage by threefold as compared with traditional CBT [33]. However, the game elements must be carefully adapted to the specific training environment [33]. One factor that has come up in our usability studies on the R2MR app is that CAF members wish to compete against other members and want to beat their "score". Thus, developing a game with an online leader-board might leverage CAF members' natural competitiveness and thus intrinsically motivate them to practice the skills.

As such, in collaboration with the University of Toronto, we have developed a military-themed preliminary prototype of a serious game. The prototype is a first-person shooting game that requires the successful completion of the resilience skills (e.g., attention control, goal setting) taught in R2MR. The game is interactive and the user's heart rate is monitored and displayed to enforce optimal arousal control during the gameplay. As a complement to the R2MR app, the prototype will serve as a functional mock-up for further development and evaluation. Future reports will expand on this initiative.

4.2.2 Digitally-Enhanced and Immersive Resilience Training Evaluation

Currently, we do not have empirical evidence that the R2MR curriculum and/or app fully meets the needs of the intended end-users (i.e., CAF personnel trainees). Furthermore, we do not have insight into what other functionality may be desired, along with its relative importance. Identifying these gaps systematically and comprehensively will allow us to understand whether future development of the mobile app is warranted and, if so, how we might prioritize and identify critical development objectives.

In order to gather information regarding the R2MR app and future potential technologically-enhanced resilience training methods, we are preparing an online survey on CAF members to identify gaps in mental health and resilience training from the perspective of our personnel and to assess their perception of whether the digital enhancement of training may reduce these gaps. The intended use of the research will be to provide user-centred guidance on how we can reduce these gaps by enhancing current and future training delivery methods using digital and immersive technologies. Further we are looking to assess the perceived usefulness/relevance of novel technologies to: (1) augment several CAF training domains (e.g., mental health, resilience training/training under stress, moral-ethical training, public-speaking), (2) augment/improve/facilitate mental health treatment-seeking, and (3) improve the ability to monitor and assess physical and mental well-being.

The results from the CAF technology training survey for mental health and resilience will guide our future evaluation of such technologies. First, in collaboration with industry partners, we intend to evaluate the potential benefits of a customized immersive "sensory reality" testbed which incorporates immersion from VR, temperature, wind, olfactory and biofeedback for resiliency training for CAF members. Further, in order to complement the R2MR serious game, we intend to examine the benefits and skill transfer of training with a serious game during stressful simulated environments incorporating haptic feedback (i.e., muscle stimulation; [34]) for enhanced immersion and consequence for actions (i.e., pain). We plan to examine the potential benefits of remote access to a health coach through an online wellness platform to encourage behaviour change and reduce barriers and encourage early access to care for CAF members. Additionally, in order to further evaluate training under stress, we are preparing to evaluate if an immersive VR public speaking environment with data-driven analytical performance feedback can be beneficial for arousal control training and the fidelity of training delivery. Specifically, we intend to evaluate the benefits of augmenting existing program processes (e.g., R2MR training delivery) with appropriate digital tools (e.g., virtual environment, automatic capture of lecturers' eye contact, prosody). These data would have the potential to strengthen the fidelity of interventions, assist in a program's capacity to scale its training, and allow for consistent and discrete fidelity and engagement monitoring.

Aligning with previous recommendations to increase the salience and immersion of psychological training (e.g., immersive moral-ethical decision-making scenarios [35], embedding DSIEs in CAF psychological training (e.g., R2MR) may facilitate knowledge acquisition, reinforce learning, and increase the long-term retention of skills through higher cognitive and emotional engagement during training. Depending on the training domain, optimal immersion and presence may be best achieved through multi-sensory DSIEs (e.g., audio-visual simulation and tactile feedback). Potential DSIE-enabled training solutions may include serious gaming (e.g., reinforcing learning through engaging digital games) and virtual reality scenarios. Augmenting the DSIE-enabled psychological training with state-of-the-art physiological monitoring (e.g., electroencephalography, heart rate variability) and biomarker profiling (e.g., stress hormones) may further optimize training through biofeedback and can elucidate factors that relate to optimal performance [34]. Specific to the potential beneficial role of DSIEs in clinical interventions, recent innovative research has alluded to the utility of virtual clinicians to improve mental health treatment outcomes [36]; therefore, this presents an opportunity for the CAF to explore the contexts and circumstances (e.g., remote locations, increasing privacy) in which virtual clinicians may provide added benefits to CAF personnel and their allies.

5.0 CONCLUSIONS

The CAF are consistently working to improve mental health and well-being, and to achieve optimal performance. Technologies may appear to be the solution but may depend on the user and the context and should be integrated as a complement to ongoing training. Thus, ongoing and collaborative research and development is crucial to provide the CAF and its allies with recommendations on mental health prevention and treatment by investigating effective ways of disseminating resiliency training and therapy using technological interventions. Further, preliminary findings highlight the importance of providing validation and content assessment of technological interventions for mental health and resilience training during task-relevant and immersive scenarios (i.e., under stress). This report reinforces the importance of ensuring that all interactions with technologies abide by human-centred design principles to adequately meet the needs of the intended users in order to optimize training compliance and, as a consequence, short-term performance improvements and long-term well-being.

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