Pattern Recognition Letters 95 (2017) 37–43

Contents lists available at ScienceDirect

Pattern Recognition Letters

journal homepage: www.elsevier.com/locate/patrec

Permanence of the CEREBRE brain biometric protocol

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A R T I C L E I N F O

Article history:
Received 11 November 2016
Available online 31 May 2017

Keywords:
Brain biometrics
Event related potentials
Biomedical imaging and signal processing
Biometric permanence

A B S T R A C T

The Cognitive Event RElated Biometric REcognition (CEREBRE) protocol recently achieved a significant benchmark in brain biometrics: namely, it was demonstrated to provide 100% identification accuracy in a pool of 50 participants. One clear question regarding this result is whether it is stable over time. Functional brain organization, of course, is constantly changing, with new memories being added and new associations being formed daily. Thus, it is reasonable to ask whether a biometric protocol based on functional brain organization– which CEREBRE is– will provide stable identification over time. Here we asked 20 participants to provide CEREBRE reference data and then return between 48 and 516 days later to challenge the system. Results indicate that even at 516 days after the initial reference was acquired the CEREBRE protocol still provides 100% identification accuracy in this pool of users. These data provide strong evidence that the biometric permanence of the CEREBRE protocol is at least stable across the 516 day inter-session lag.

1. Introduction

Brain biometrics offer some interesting advantages over conventional biometrics like fingerprints or DNA. In particular, brain biometrics have the potential to protect not only the classified information, but also the user of the biometric system. This is because, unlike fingerprints and DNA (and indeed, most other conventional biometrics), brain biometrics based on the brains electromagnetic signature cannot be acquired from a deceased person [25] or when the head is detached from the body, meaning that causing physical damage to a person to acquire their brain biometric is not possible. Even better, brain biometrics are likely to be difficult to coerce, as coercion (e.g., through threats of violence or blackmail) is likely to put significant stress on the user, and stress is well known to strongly impact brain electrical activity (e.g., [5]) – likely enough to prevent an acutely stressed individual from authenticating into a brain biometric system. Additionally, individuals brain electrical activity is not under conscious control or awareness, meaning that brain electrical biometrics can not be intentionally disclosed in the way a password can be. (e.g., [9]). Given these interesting advantages (among others, such as brain biometric cancellability and the difficulty of collecting brain electrical activity surreptitiously; see [23] for review), significant efforts have been placed into developing robust brain biometric protocols (reviews in [1,3]). Recently, our group passed an important benchmark by demonstrating that the CEREBRE (Cerebral Event-RElated Biometric REcognition) protocol can obtain 100% identification accuracy in a pool of 50 users [2,23]. The CEREBRE protocol draws upon multiple functional brain networks, in order to elicit brain electrical signals that are highly individual. For example, the CEREBRE protocol calls upon the gustatory/appetitive system, by presenting participants with a range of food stimuli, and tapping into individual taste preferences. hlThe CEREBRE protocol hlalso calls upon the semantic memory system, by presenting participants with a range of difficult vocabulary words, and mapping out the size and shape of the individuals semantic network. The protocol also calls upon the facial recognition system, the primary visual system, and the decision making system. The CEREBRE protocol works because it is extremely unlikely that any two individuals will have identical taste preferences AND identical vocabularies AND identical facial preference AND identical visual systems AND identical decision making systems.

However, because the CEREBRE protocol does call upon functional brain organization (i.e., not only brain anatomy, but how the brain is representing information), it is reasonable to question how stable CEREBRE biometrics will be over time [18]. As one example, it is easy to imagine than an individuals gustatory preferences could change sharply after an incident with food poisoning; similarly, an individuals vocabulary could easily expand through habitual crossword puzzle use or artifice such as word-of-the-day calendars. And, we argued above that one advantage of brain biometrics is that they are likely to be disrupted by acute stress (such as the threat of violence), however, it would be a significant disadvan-

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http://dx.doi.org/10.1016/j.patrec.2017.05.031
0167-8655/

tage if brain biometrics were disrupted by more mundane stresses, such as being late to work or the coffee machine being broken. For these reasons, here, we sought to investigate formally the biometric permanence of the CEREBRE protocol. In particular, we were interested in determining whether CEREBRE identification accuracy would decrease across time between reference and challenge sessions. To this end, we asked a pool of 20 participants to provide CEREBRE reference data, and then we called them back to the lab after a delay of between 48 and 516 days after the first session to provide a challenge CEREBRE biometric. This allows us to determine whether CEREBRE identification accuracy degrades across this span. Even password authentication, which is in theory entirely permanent, is typically canceled and changed on the order of every 30 days [19] to a year in secure systems [26]. Therefore, in order for CEREBRE to even be considered for that level of adoption, it would be beneficial to be able to demonstrate that level of permanence. However, it also easily could be the case that the transient nature of human memories and preferences are reflected in the brain electrical activity collected by CEREBRE to an extent that prevents the protocol from maintaining permanence over time. This is what we will determine below.

Some prior work in the domain of neuropsychology has addressed the test-retest reliability of ERPs (e.g., [10]), and, indeed, it is well established that ERP components in general (e.g., the Visual N1, the N400) are very stable over time (going back to, for example, [7]). However, the current work addresses a slightly different question. That is, we ask not whether ERP components and their amplitudes are stable over time, but whether the differences in components elicited by different individuals are stable over time. That is, we are specifically interested in whether the small portions of the ERP that are biometrically unique are stable over time, not in whether ERP components are stable over time.To our knowledge, only one other study has examined brain biometric permanence over this long a span, and none have examined the permanence of the CEREBRE protocol in particular (c.f., 1.5 months in [18]).

2. Methods

Because we were specifically interested in investigating the permanence of the CEREBRE protocol, we followed its methods exactly. These methods are reproduced below, as described in [23].

2.1. Participants

A total of 20 individuals, ranging in age from 18 to 28 years old (age reported for each participants initial session), participated (14 female, mean age 19.95). No particular screening was performed on these participants, as the goal of a biometric is to be as broadly applicable as possible. Participants were compensated with either course credit or money. The Internal Review Board of Binghamton University approved the experimental protocol. Participants each completed two CEREBRE sessions, spaced between 48 and 516 days apart (mean 282 days). Fig. 1 displays all inter-session lags.

2.2. Materials

Materials were those previously described in use in the CEREBRE protocol. These were: 100 sine gratings, 100 low frequency words, 100 images of foods, and 100 celebrity faces. Sine gratings were randomly generated for each participant using the following parameters: orientation of the grating ranged randomly between 0 and 360°, number of pixels per period of the sine wave ranged randomly between 1 and 80. Sine gratings generated in this manner were then multiplied by a Gaussian kernel where one standard deviation of the Gaussian covered a random number of periods of

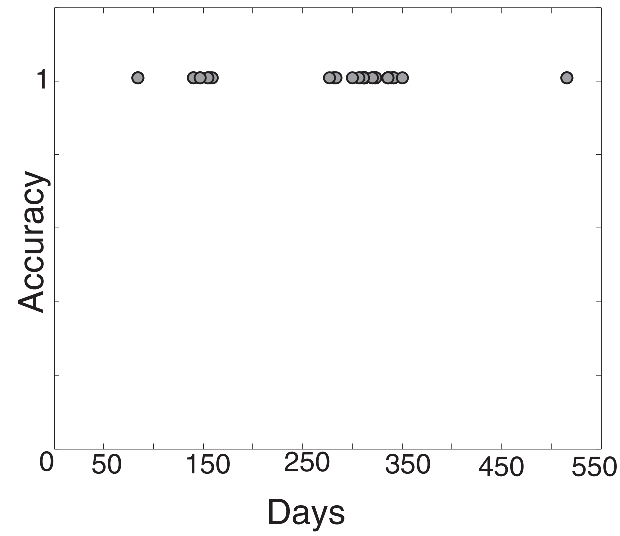

Fig. 1. Identification accuracy over time. Each dot represents one participant. Every participant was identified correctly, even at the longest duration between reference and challenge sessions (516 days).

the sine wave. Resulting sine gratings were centered on a 500 × 500 pixel uniform grey background. To create color versions of the sine gratings to serve as targets in the color detection task, a random, high saturation, color mask was overlain on a random 25% of them.

Low frequency words were drawn from the Graduate Record Exam (GRE) with the constraint that they all have less than 10 letters. Words were printed in black Arial font centered on a uniform 500 × 500 pixel grey background. To create color versions of the words to serve as targets in the color detection task, the color of the font was then randomly re-selected from the high saturated half of the color wheel for a random 25% of the words.

The foods were selected on the basis of a norming study conducted in the lab. In the norming study, 44 participants who did not take part in the ERP studies were asked to list 10 foods they love and 10 foods that they hate. From the full list of responses, the 10 most bipolar foods were selected; that is, the 10 foods that were listed most often in both the love and hate categories. Then, 10 color instances of each of these 10 foods (for a total of 100 images) were sought from Google images. Desaturated (black and white) copies of all 100 food images were created, and each participant saw 75 color foods and a random selection of 25 desaturated images (selected without replacement). The exact same procedure, including a norming, was followed to select the celebrity faces.

These particular image types were selected because they each activate a distinct brain system that is likely to be different from person to person. The sine gratings tap the primary visual system (e.g., [4]), the low frequency words tap the semantic memory system (e.g.,[15]), the foods tap the gustatory/appetitive system [20], the faces tap the facial recognition system (see [22] for review), and requiring participants to perform a task taps the decision making system (review in [6]).

2.3. Procedure

For EEG acquisition, participants were seated in an RF-shielded, sound-attenuated recording chamber and positioned 75 cm away from a 24 in LCD monitor with a resolution of 1920 × 1080, a black-to-white response rate of 1 ms, and a refresh rate of 60 Hz. Participants were allowed to see their EEG and were given a short demonstration of trial structure, including when it was and was not acceptable to blink their eyes, and were informed that their