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Increasing the mobility of EEG data collection using a Latte Panda computer

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ABSTRACT

Background: Electroencephalography (EEG) experiments often require several computers to ensure accurate stimulus presentation and data collection. However, this requirement can make it more difficult to perform such experiments in mobile settings within, or outside, the laboratory.
New method: Computer miniaturisation and increasing processing power allow for EEG experiments to become more portable. Our goal is to show that a Latte Panda, a small Windows 10 computer, can be used to accurately collect EEG data in a similar manner to a laptop. Using a stationary bike, we also suggest that the Latte Panda will allow for more portable EEG experiments.
Results: Significant and reliable MMN and P3 responses, event-related potentials (ERPs) typically associated with auditory oddball tasks, were observed and were consistent when using either the laptop or Latte Panda for EEG data collection. Similar MMN and P3 ERPs were also measured in the sitting and stationary biking conditions while using a Latte Panda for data collection.
Comparison with existing method: Data recorded by the Latte Panda computer produced comparable and equally reliable results to the laptop. As well, similar ERPs during sitting and biking would suggest that EEG experiments can be conducted in more mobile situations despite the increased noise and artifacts associated with muscle movement.
Conclusions: Our results show that the Latte Panda is a low-cost, more portable alternative to a laptop computer for recording EEG data. Such a device will further allow for more portable and mobile EEG experimentation in a wider variety of environments.

1. Introduction

Electroencephalography (EEG) is commonly used to measure brain activity during laboratory experiments. However, due to the sensitive nature of EEG, these experiments are carried out in highly isolated and controlled environments. The experiments often take place in a Faraday cage, isolating the participant from sound and electrical noise, and the participants are required to move as little as possible to limit noise and contamination in the EEG data. These restrictions limit the applicability of EEG results to settings outside the laboratory. In order to identify ways to make EEG experimentation more accessible and portable, the current study investigates alternative methods of EEG data recording using a Latte Panda computer. The Latte Panda is a small device which runs Windows 10, contains a 1.8 GHz Intel Quad Core Processor and has 4 GB of RAM. It is roughly 88 by 70 mm and costs approximately $150.

Previous research by Kuziek et al. (2017) tested other methods to increase the portability of EEG experiments. The authors were able to show that a Raspberry Pi 2 computer, henceforth referred to as the Pi 2, can be used in place of a PC for presenting experimental stimuli and accurately marking stimulus onset in the recorded EEG data. The Pi 2 is a small, portable and inexpensive computer, making it ideal for conducting mobile EEG experiments. In their 2017 paper, Kuziek et al. used the Pi 2 to present stimuli in an auditory oddball task, and to send triggers to mark the timing of tone onset on the EEG data. The Pi 2 effectively ran the experiment, and reliably elicited Mismatched Negativity (MMN) and Positive 300 (P3) event-related potentials (ERP). Both ERPs were comparable to those elicited from a traditional desktop PC running the same task, despite larger variation in trigger-to-tone latency in the Pi 2 experiments. Both the MMN and P3 ERPs typically occur following the presentation of a target auditory tone. The MMN ERP is a difference in negative voltage that occurs roughly 200 ms following tone presentation while the P3 ERP is a positive deflection in voltage that occurs roughly 300 ms following tone presentation.

Scanlon et al. (2017) tested the Pi 2 outside. They had participants ride a bike along a busy street while completing an auditory oddball task. All the equipment, including the Pi 2, amplifier and recording

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laptop, was placed in a backpack worn by the participant throughout the experiment. This paradigm elicited significant MMN and P3 responses comparable to those found indoors, suggesting the Pi 2 is a reliable way to conduct EEG experiments in a mobile, external environment. While the Pi 2 reliably presents stimuli and marks data in mobile experiments, it necessitates an EEG cap and expensive, cumbersome equipment such as an amplifier and laptop.

Recently developed portable EEG systems, such as the Emotiv EPOC, may also be used for data collection. de Lissa et al. (2015) compared N170 ERP data collected from either the Emotiv EPOC or the Neuroscan system while participants were shown either face or non-face stimuli. The data recording abilities of the EPOC and Neuroscan systems were not statistically different. Badcock et al. (2013) and Badcock et al. (2015) also compared the two systems, looking at the P1, N1, P2, N2 and P3 ERPs, elicited during an auditory oddball task. They found the EPOC was reliable in eliciting the P1, N1, P2, N2 and P3 ERPs. However, it was not reliable in eliciting an MMN response. Debener et al. (2012) also tested the effectiveness of the EPOC using an auditory oddball task. Participants either sat still while indoors or walked outside while quietly counting target tones. A reliable P3 response was elicited in both conditions and classification of these waveforms was above chance, although mean accuracy was higher when the task was completed indoors compared to outside. Differences in classification can likely, in part, be due to the increased artifactual noise associated with increased movement in the outdoor condition. Similar research using other portable EEG devices was also performed by Zink et al. (2016). Participants completed a three-stimulus auditory oddball task while sitting still, peddling a stationary bike, or biking outdoors while data was recorded using the SMARTING mobile EEG amplifier designed by mBrainTrain. Significant P3 and N1 waveforms were observed in each condition, although a smaller P3 was observed for the biking outdoors condition. As expected, artifactual noise was found to be greatest in the moving condition compared to the sitting and stationary peddling conditions. The previously described studies effectively demonstrate that currently available portable EEG amplifiers/electrodes can be effectively used for traditional EEG experiments along with similar experiments in much more mobile settings where movement and muscle artifacts are more prominent.

While portable EEG devices such as the EPOC and SMARTING allow for smaller EEG amplifiers and electrodes, other electronics devices typically utilised in EEG experiments may be further miniaturised. The goal of the current study was to utilise current technology, specifically the Latte Panda computer, to make the recording and saving of the collected EEG data more mobile while using more conventional EEG electrodes and amplifiers. We performed two experiments in the hopes of successfully demonstrating the effectiveness of the Latte Panda as an EEG recording device. For the first we wished to expand on preliminary work our lab conducted which tested the reliability of the Pi 2 in presenting auditory oddball stimuli for EEG experiments and marking stimulus onset in the recorded EEG data. Our goal for experiment one was to directly compare EEG data recorded by either the Latte Panda or a laptop to understand if the Latte Panda impedes EEG data collection and ERP generation in any meaningful way when compared to data collected with a laptop computer. If the Latte Panda is capable of accurately recording EEG data then ERPs derived from the recorded data will be statistically similar to those ERPs derived from EEG data recorded using a laptop PC. If the Latte Panda is unable to reliably collect EEG data, perhaps due to hardware/software incompatibilities, power requirements, or processing power, then we would expect our ERPs to significantly differ from those obtained using a laptop. For the second experiment our goal was to contribute to results obtained by other labs by using the Latte Panda in a more mobile auditory oddball experiment where participants would perform the experimental task while either sitting or slowly peddling a stationary bike. While we expect to observe increased artifact noise due to motion and muscle activity, our goal with experiment two is to show that the Latte Panda can be used in a more portable experimental setting and that the EEG data collected in both the sitting and biking conditions will be of comparable quality. In line with previous research on mobile experimentation, we expected the peddling condition to produce smaller P3 and MMN waveforms associated with increased movement artefacts. Contrasting with previous research, the Latte Panda will act as a replacement for a laptop computer for recording the EEG data to further reduce the weight, space, and cost of equipment. A traditional, typically stationary commercial amplifier and active-wet electrodes will also be used in place of a mobile amplifier or consumer EEG headband such as the EPOC. While not as inexpensive as a consumer system, we hope the advantages offered by the commercial amplifier will help to accommodate for motion and noise artifacts associated with peddling and muscle activity. All necessary equipment needed for stimulus presentation and data recording was put inside a backpack which the participant wore while completing the task. With a system comprising the Latte Panda and the Pi 2 in place of a desktop PC and laptop PC, EEG experimentation becomes much more affordable and portable. Increased portability will greatly improve the external validity of EEG experiments, and more affordable systems will increase the breadth of EEG studies that can be conducted.

2. Methods- experiment one

2.1. Participants

A total of 14 members of the university community participated in experiment one. Data from one participant was removed due to recording issues, only the remaining 13 participants are included in further analyses (mean age = 21.46; age range = 18–31; 4 males). Each participant completed two identical auditory oddball tasks with EEG data being recorded by either a Latte Panda computer or a laptop PC computer. The order of the EEG recording device, either Latte Panda or laptop, was counterbalanced. Participants were all right-handed, and all had normal or corrected normal vision and no history of neurological problems. All participants gave informed consent, and were either given course credit for an introductory psychology course, or else given an honorarium of $10/hour for their time. The experimental procedures were approved by the internal Research Ethics Board of the University of Alberta.

2.2. Materials & procedure

Participants completed two auditory oddball tasks. Sony in-ear headphones played one of two tones, either 1500 Hz target tones or 1000 Hz standard tones. Target tones were presented 20% of the time while standard tones were presented 80% of the time. Each tone was sampled at 44,100 Hz, presented for a duration of 16 ms through two speakers, and contained a 2 ms linear ramp up and down. A consistent, comfortable listening volume was used throughout each experiment. Participants were asked to sit still and fixate on a 1° white cross in the center of a black background that stayed constant throughout the auditory task. Participants were instructed to move only their right hand to press the spacebar on a keyboard placed in front of them each time a target tone was presented. Following the presentation of a standard tone, participants were instructed to with-hold any response.

Participants were seated 57-cm away from a 1920 × 1080 pixel ViewPixx/EEG LED monitor running at 120 Hz with simulated-backlight rastering. Stimuli were presented using a Raspberry Pi 2 model B computer running version 3.18 of the Raspbian Wheezy operating system, and version 2.7.2 of the Python programming language. Video output was via the onboard VideoCore IV 3D graphics processor connected through HDMI, and audio output was via the onboard 900 MHz quad-core ARM Cortex-A7 CPU connected through a 3.5 mm audio cable. The TTL pulses were sent to the amplifier via a parallel port to serial port cable connected to the GPIO pins of the Raspberry Pi