 doi:10.20944/preprints202207.0120.v1

Article

Using brains as sensors of the magnetic fields produced by other brains

Énora Jeuland[1,2], Matthieu Lenne[1,3], Florence Jarry[1,4] & J. Bruno Debruille[1, 3, 5, *]

[1] Douglas Mental Health University Institute, Montreal, QC, Canada
[2] Department of Psychology, McGill University, Montreal, QC, Canada
[3] Department of Neurology and Neurosurgery, McGill University, Montreal, QC, Canada
[4] Department of Cognitive Science, McGill University, Montreal, QC, Canada
[5] Department of Psychiatry, McGill University, Montreal, QC, Canada
* Corresponding author: bruno.debruille@mcgill.ca

Abstract: The effects of transcranial magnetic stimulations (TMS) show that the human brain is impacted by some magnetic fields (EMFs). Moreover, after a delay, it produces potentials that reveal a subsequent processing of this impact. The human brain might also be sensitive to very weak magnetic fields of extremely low frequencies (vwEMFelf). Namely, to the vwEMelf produced by the brain of other persons when they process visual stimuli. In effect, two studies report that the event-related brain potentials (ERPs) that are evoked by presenting a picture to a participant can be modulated by simultaneously presenting a picture to a partner. To confirm it here, we followed most of the methods of these studies. We recorded the ERPs evoked by presenting, at each trial, the photograph of a face. Simultaneously and, most importantly, privately, we presented a partner with the same or with a different face photograph. ERPs of participants were found to depend on that sameness ($p<0.001$), unbeknownst to them. These joint processing effects (JPEs), confirm a sensitivity of the human brain to the vwEMFelf produced by other brains.

Keywords: Brain, sensitivity to EMFs, EEG, event-related brain potentials, LPP or late posterior positivity, joint processing effects (JPEs)

1. Introduction

In animals, the existence of magnetoreception is well established. Three major hypotheses have been developed to account for it: A) various forms of electrical induction [1-3], B) a chemical/quantum compass involving subtle interactions with a photoactive pigment [4] like cryptochrome [5,6], and C) hypotheses based on particular cell components including biologically-precipitated magnetite similar to those of magneto tactic microorganisms [7]. Yet another mechanism has been proposed to explain non-specific effects of magnetic fields: the mixing of the quantum levels of magnetic moments of rotating macromolecules [8].

In humans, a sensitivity to strong magnetic fields has been demonstrated for years. Transcranial magnetic stimulations (TMS) evoke reliable brain potentials [e.g., 9-11]. Interestingly, recently, human brains have been found to be also sensitive to weak magnetic fields [12]. These weak fields also induce delayed brain potentials, which reveal a processing of the information that continues after the end of the external stimulation.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

Moreover, this recent study shows that various brain strategies can spontaneously develop to either further process the information gathered through this magnetic sensitivity or to discard it.

On the other hand, we know that, when brains are processing usual stimuli, they are themselves *producing* magnetic fields. These fields are very weak and of extremely low frequencies (vwEMFelf, i.e., 0.5 to 50 Hz). These vwEMelf have been recorded externally in hundreds of studies using magneto-encephalography (i. e., MEG, e.g., [13]).

One can then wonder whether human brains could be sensitive to the vwEMFs they themselves produce.[1] One can also wonder whether they could be sensitive to the vwEMFs produced by the brain of others,[2] when they process stimuli.

The results of Bouten et al. (2014) [20] and Haffar et al. [21] support this possibility.[3] In these two studies, the authors examined whether the event-related potentials (ERPs) evoked by a stimulus, a picture, depend on the picture simultaneously, but, most importantly, privately, presented to another person: a partner whose head was close (i. e., 40 cm) to that of the participant. Both studies reported that the ERPs obtained depended on whether the two pictures were the same or not. These effects of sameness were seen on two ERPs, the so-called N400 and the late posterior positivity, the LPP. The mean voltage of these two potentials was significantly ($p<0.001$) more positive in the block of trials where the partner was presented with the same picture as the participant than in the block of trials where (s)he was presented with a different picture.

Nevertheless, the number of participants that had to be used in those two studies to obtain decent p values were relatively large (i.e., 32). Moreover, the ERP effects found were not clearly seen at all electrode sites. These data have thus been reprocessed to more accurately identify the circumstances in which the effects occur. It appeared that the effects might be more robust when focusing only on the ERPs obtained after it was announced to the two partner-participants of each pair that they will be presented with different images.[4]

In the present attempt at replicating the sensitivity found in [20 & 21], we thus used only this announcement. On the other hand, we looked at whether the conclusions of these studies could be extended to other circumstances. Namely, whether the effects could also be obtained 1) when using a type of images other than that used in [20, 21] and 2) when the two partners of each pair of participants were placed a bit farther from each other and in different (but adjacent) rooms.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

2. Methods

2.1. Participants

Participants were recruited as in the two previous studies [20 & 21]. In the eligibility questionnaire, candidates were asked about their habits and their personal and family medical history. Pairs including an individual who reported consuming more than twelve alcoholic beverages per week, a regular use of recreational drugs, a personal history of psychiatric disorder, a use of a medication related to such a disorder, or a first-degree relative with a history of schizophrenia or bipolar disorder, were not eligible.

Eight pairs of partners were then selected among those who had answered the adds we had placed in social media, who had known each other for at least 3 years and who were between 18 and 30 years of age. One participant had to be discarded after the testing because his EEG was too artifacted. The remaining 15 participants included 13 female- and 2 male-participants whose mean age was 20.8 (SD 3.0). All pairs were friends. There was no siblings or romantic partners. Each participant had to fill-up the McGill friendship questionnaire [23] when (s)he was alone in order to rate the degree to which (s)he was familiar with his/her partner. The average score of the partner-participants at this questionnaire was 7.3 (SD: 0.64).

Participants had normal or corrected-to-normal vision. Seven were in college (CEGEP), 6 were undergraduate university students, 2 did not mention their level.

2.2. Consent

The informed consent form used was approved by the Research Ethics Board of the Douglas Mental Health University Institute where the study was conducted. This board, which follows the principles of the Declaration of Helsinki, also approved the study itself. Before the experiment, candidate-participants were sent the informed consent form and, when applicable, a form mentioning the risks of participating in a research project during the COVID-19 pandemic. They were called by the experimenter to complete the eligibility questionnaire and, if meeting the criteria, to schedule the date of the testing. During this phone call, the two candidates of each pair gave their oral consent for participating in the study and for coming to the lab during the COVID-19 pandemic when applicable. When arriving at the laboratory, both partner-participants signed the informed consent form (Douglas REB #12/12).

2.3. Stimuli

The stimuli used were 300 faces taken from the Multipurpose bank of European Descent faces (the MED-bank, [24]). This bank only consists of color front views of faces of unknown people (600 in total) who were asked to remain neutral when they were photographed. These people all accepted their face photograph to be used for research purpose. At each trial of the present study, one such face was separately and privately presented to each of the two partners of each pair. These two presentations occurred exactly at the same time at each trial. The two images were either identical (same-stimulus trial) or different (different-stimuli trial). Just before the presentation, it was announced to participants that they would be seeing different images than their partner. All the trials including two identical face-images were placed in the “same-stimuli block-

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

condition" and all the trials including two different faces, in the "different-stimuli block-condition".

In order to make sure that ERP differences across the two block-conditions could not be due to the particular face photographs used in each of these blocks, the images used in one condition for one pair of partner-participants were used in the other condition for the next pair. Participants never saw a face photograph more than once.

2.4. Procedure[5]

As in [20 & 21] during each of the two blocks of trials, each double picture was displayed for a 1000 ms duration and was immediately followed by a black cross the duration of which was randomized from 790 to 1500 ms to prevent the development of a contingent negative variation [25]. Before the two blocks, a sentence indicated that participants had to try to memorize the faces and announced that these faces were going to be different across partners. This announcement was concordant with reality for one of two the blocks and false for the other, where the same face photograph was presented to each of the two partner-participants. The verbatim was "Try to remember the next 100 images, your partner will be seeing different images".

Each individual was seated in front of a computer screen in a room that was adjacent to the room in which their partner was seated. The wall separating the two rooms had a double glass window that was covered by an opaque curtain on both sides. The curtains were open during the electrode cap setup so that partners could see each other. This was done to help them feel in the presence of their partner later, that is, during the experiment. The curtains were closed right before the start of the experiment and for its entire duration to prevent participants from seeing the face shown to partners and to prevent any detection of the partner's reactions to his/her stimuli.

Cameras filmed the partner-participants from behind to check, offline, that they did not move the curtains. These cameras were also recording sounds to verify that participants did not emit any sound that could have been heard by his/her partner and could have provided an indication as to whether the face-image presented to the participant was identical to the one presented to the partner. These videos can be seen in the additional materials of the present study. Figure 1 below shows the experimental setup for each pair of partner-participants (Pps).

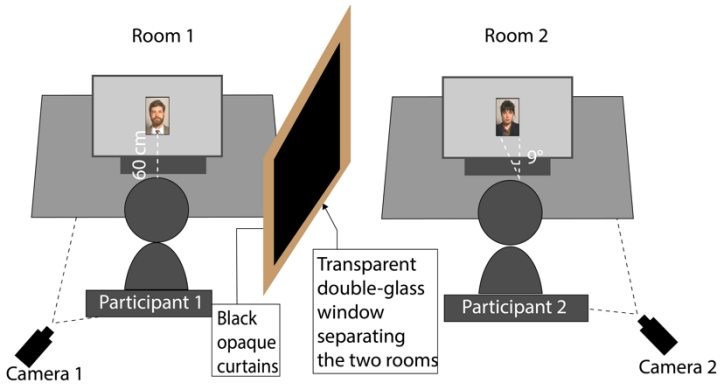

Fig. 1. Schema of the lab setting used.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

After the presentation of the two blocks of trials, each partner-participant went through a debriefing question where (s)he was asked "Did you feel deceived at any point during the experiment?"

2.5. Data acquisition

For each participant of each pair, the electroencephalogram (EEG) was recorded from 28 tin electrodes of a cap from Electro-Cap International. They were located following the modified expanded 10-20 system [26] and using the Fz, FCz, Cz, Pz, Fp1/2, F3/4, Fc3/4, C3/4, Cp3/4, P3/4, O1/2, F7/8, Ft7/8, T3/4, Tp7/8 and T5/6 scalp sites. The right ear lobe was used as the reference and the ground was placed 2 cm ahead of Fz. The cap of each of the two partners was connected to one of the two separate sets of amplifiers, both having a 20,000 gain. Their high- and low-pass filters had their half-amplitude cut-offs adjusted at 0.01 Hz and 100 Hz, respectively. A 60Hz electronic notch filter was also used. EEG signals were digitized at a 512 Hz sampling rate and stored in a single file of 56 channels (28 x 2). Artifacts due to blinks, vertical and horizontal eye movements as well as myogram were detected and corrected in each participant by using the independent component analysis (ICA) of EEGLab, a free Matlab plugin. This was done after using the 100hz low-pass filter on EEGs. Components which, according to the ICA, had more than 90% probability of being due to muscle or eye artifacts were removed.

2.6. Data processing and measures

Baselines were set by computing the mean voltage in the -200 to 0 ms time window for each electrode and by subtracting this mean value to each point of the -200 to 1200 ms EEG epoch. Trials that included analog-to-digital clipping lasted longer than 100 ms and/or voltages outside of the +/- 100 μV range were rejected. On average, 91.7 (SD 11.4) trials were accepted in the same-stimulus block-condition and 93.1 (SD 9.6) in the different-stimulus block-condition (in supplementary materials).

To obtain two ERPs, one for each of the 2 conditions, the remaining EEG epochs corresponding to the trials of each condition were averaged in a 1400 ms window beginning 200 ms before the onset of the stimulus and ending 1200 ms after the onset. Because of poor EEG, ERPs at one channel for two participants and ERPs for 4 channels for one participant had to be recomputed using a linear combination of ERPs at nearby electrodes (see supplementary material). As in Bouten et al. (2014) [20], mean voltages were then measured at all electrodes, for each of the two conditions and all participants in the N400 time window (350-550 ms after stimulus onset) and in the LPP time window (650-950 ms after the onset).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

2.7. Statistical analyses

For each time-window, the measures were analyzed through a repeated-measure ANOVAs using a multivariate approach run with the version 21 of the IBM SPSS software. A two-factor analysis scheme was used, including sameness (different vs. same face photograph across the two participants) and electrodes (28 levels) as within-subject factors. The Greenhouse and Geisser's (1959) [27] adjustment of the degrees of freedom was used to palliate to the heterogeneity of variances across electrodes, in which case the original F values and degrees of freedom are given together with the corrected p values.

The Benjamini-Hochberg (1995) [28] false discovery rate (B-H FDR) procedure was then used to judge the results of each series of tests. P-values were thus first ranked from the most to the least significant. One B-H FDR threshold for each of these p-value was then computed by dividing its rank by the total number of tests and by multiplying the result by the false discovery rate chosen, namely, 10%. The p-value was declared significant if it was smaller than that threshold.

3. Results

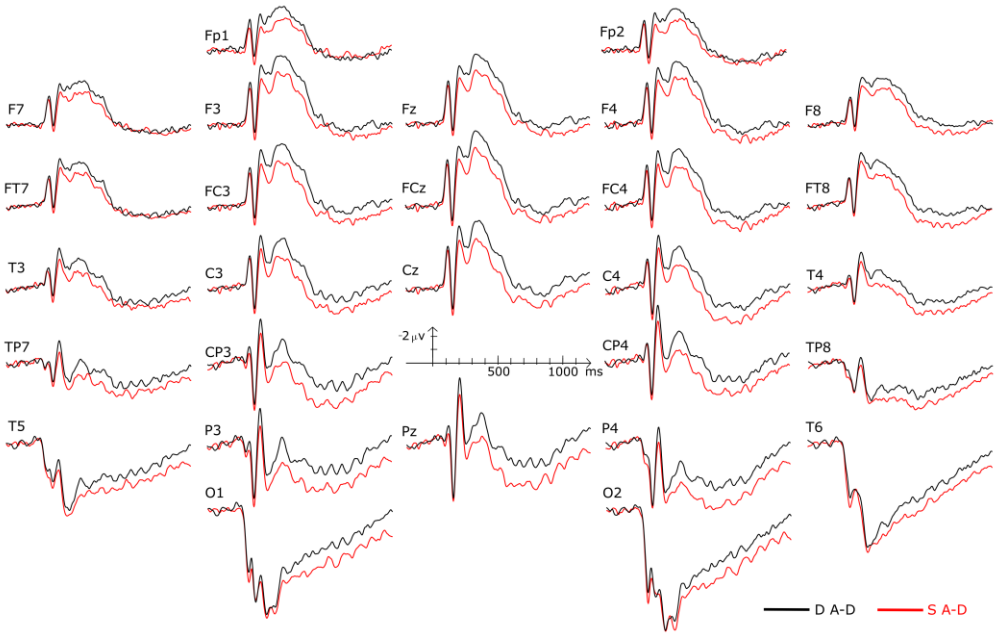

Figure 2. Grand average of the ERPs evoked by face photographs in the 15 participants during the memorization task. Red lines correspond to S A-D, the block where, at each trial, the two partners' participants of each pair were privately presented with the same face photograph. Black lines, for D A-D, the block where, at each trial, they were presented with a face different from that shown to their partner. Just before those two blocks, all participants were told that the faces they will see will be different from those shown to their partner.

Figure 2 (above) shows the ERPs evoked by the face photographs of the block where the two face photographs of each trial were always the same and those of the block where they were different. The former were more positive than the latter at all electrodes in the N400 time window and at all electrodes except Fp1/2 in the LPP time window. The distribution of that difference on the scalp is illustrated by Figure 3 below. As

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

displayed on tables 1, 2 and 3 (below), these differences were significant in both time windows. This was observed even though participants did not know the face photograph their partner was looking at.

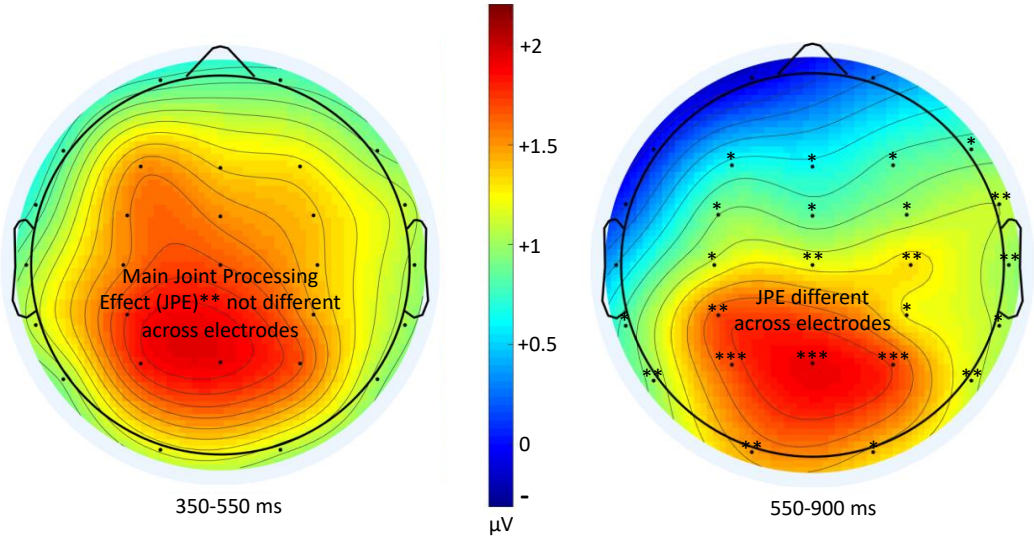

Figure 3. Spline-interpolated isovoltage scalp-maps of the subtraction of the mean voltages of the ERPs obtained in the different-stimulus block condition (D A-D) from the mean voltages of the ERPs obtained in the same-stimulus block conditions (S A-D) in the 350- 550 ms- and in the 500-900 ms-time window. * is for $0.05 > p > 0.01$; ** is for $0.01 > p > 0.001$; *** is for $0.001 > p > 0.0001$.

Checking the two videos made during the testing of each pair of participants did not reveal any participant who drew the curtain and saw the face-photograph presented to his/her partner or who made a noise that could have given to the partner an indication on the face-photograph (s)he was presented with. These videos have been added to supplementary materials.

The question: "Did you feel deceived at any point during the experiment?" asked to participants at the debriefing session did not reveal any feeling of deception. No participant seems to have detected consciously that the announcement was false for the same-stimulus block-condition. No participant mentioned that his/her partner was looking at the same face-photograph as (s)he was during that block. On the other hand, no participant reported being deceived by the absence of a memory test at the end of the memorization task.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

TABLE 1. Results of the omnibus ANOVA and of the Benjamini-Hochberg FDR (B-H) technique run on the mean voltage of ERPs measured in the 350-550 and the 550-900ms time-windows at all electrode sites.

Number of tests (N)	Factors Group (G, 3 levels) Time window (T, 3 levels) Electrode (E, 28 levels)	df	F-values	p-values (Greenhouse-Geisser)	Rank (r) of the p-value	Critical value = FDR * (r/N)	Significant according to B-H	Effect size (η_p^2)	Observed Power (alpha=0.05)
7	E x T	27, 378	49	7.0×10^{-12}	1	0.015	yes	0.78	1.00
	E	27, 378	20	4.1×10^{-7}	2	0.029	yes	0.59	1.00
	T	1, 14	64	1.3×10^{-6}	3	0.043	yes	0.82	1.00
	J	1, 14	13	0.0029	4	0.057	yes	0.48	0.92
	J x E x T	27, 378	4.2	0.01	5	0.072	yes	0.23	0.87
	J x E	27, 378	3.2	0.01	6	0.086	yes	0.19	0.88
	J x T	1, 14	1.0	0.33	7	0.100	no	0.07	0.16

TABLE 2. Results of the repeated-measure ANOVA run on the mean voltage of ERPs measured in the 350-550 time-window only, in order to deconvolve the J x T x E interaction reported in Table 1.

Number of tests (N)	Factors JPE (J, 2 levels) Electrode (E, 28 levels)	df	F-values	p-values (Greenhouse-Geisser)	Rank (r) of the p-value	Critical value = FDR * (r/N)	Significant according to B-H	Effect size (η_p^2)	Observed Power (alpha=0.05)
3	J	1, 14	15	0.0018	2	0.067	yes	0.51	0.95
	J x E	27, 378	1.9	0.113	3	0.100	no	0.27	0.99
	E	27, 378	32	1.8×10^{-9}	1	0.033	yes	.695	1.0

TABLE 3. Results of the repeated-measure ANOVA run on the mean voltage of ERPs measured in the 550-900 time-window only, in order to deconvolve the J x T x E interaction reported in Table 1.

Number of tests (N)	Factors JPE (J, 2 levels) Electrode (E, 28 levels)	df	F-values	p-values (Greenhouse-Geisser)	Rank (r) of the p-value	Critical value = FDR * (r/N)	Significant according to B-H	Effect size (η_p^2)	Observed Power (alpha=0.05)
3	J	1, 14	8.2	0.012	3	0.100	no	0.37	0.76
	J x E	27, 378	5.1	2.6×10^{-4}	1	0.033	yes	0.27	0.99
	E	27, 378	9.2	3.2×10^{-4}	2	0.067	yes	0.4	0.98

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

TABLE 4. Results of T-Tests run on the mean voltages of the ERPs measured in the 550-900ms time window at all electrodes in order to deconvolve the J x E interaction reported in Table 3.

Electrode	df	P-values (1-tailed)	Rank of P-value	Critical value = FDR * (r/N)	Significant according to the BH procedure (Yes/No)
P4	1, 14	0.00018	1	0.004	Yes
Pz	1, 14	0.00038	2	0.007	Yes
P3	1, 14	0.00095	3	0.011	Yes
Cp3	1, 14	0.0010	4	0.014	Yes
T6	1, 14	0.0011	5	0.018	Yes
C4	1, 14	0.0012	6	0.021	Yes
O1	1, 14	0.0014	7	0.025	Yes
Ft8	1, 14	0.0015	8	0.029	Yes
Cz	1, 14	0.0028	9	0.032	Yes
T5	1, 14	0.0033	10	0.036	Yes
T4	1, 14	0.0033	11	0.039	Yes
O2	1, 14	0.01	12	0.043	Yes
FC4	1, 14	0.01	13	0.046	Yes
FC3	1, 14	0.01	14	0.05	Yes
Tp8	1, 14	0.01	15	0.054	Yes
F4	1, 14	0.02	16	0.057	Yes
FcZ	1, 14	0.02	17	0.061	Yes
C3	1, 14	0.03	18	0.064	Yes
F8	1, 14	0.04	19	0.068	Yes
Cp4	1, 14	0.04	20	0.071	Yes
F3	1, 14	0.06	21	0.075	Yes
Fz	1, 14	0.06	22	0.079	Yes
Tp7	1, 14	0.08	23	0.082	Yes
T3	1, 14	0.14	24	0.086	No
Fp2	1, 14	0.24	25	0.089	No
Fp1	1, 14	0.4	26	0.093	No
F7	1, 14	0.44	27	0.096	No
Ft7	1, 14	0.47	28	0.1	No

4. Discussion

The event-related brain potentials (ERPs) evoked by the face-photographs shown to our participants were thus found to depend on whether or not the partner of each participant was presented with the same face photograph. These differences were obtained whereas participants could not see the stimulus presented to their partner. They thus had no indication on whether or not the face they were presented with was the same as the one presented to their partner. The ERP dependence found can thus not happen without a sensitivity of the brain to the very weak magnetic fields of extremely low frequencies

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 July 2022 doi:10.20944/preprints202207.0120.v1

(vwMFesf) produced by the brain of the partner when (s)he processes the visual stimuli used.

The ERPs differences found in the time windows where they were obtained in the two previous studies [20 & 21], that is, in the N400 (350-550 ms) and in the LPP (550-950 ms) time window. Moreover, these differences were in the same direction as those of these previous studies. Namely, ERPs were found to be more positive in those time-windows when the partner was presented with the same stimuli as the participant than when the partner was presented with a different one. The present results thus replicate those found twice before. In addition, they are more robust. Indeed, decent p values (i.e., down to 0.00018, see Table 4) were obtained with only 15 participants whereas, it took 32 participants in the two previous studies to approach that level. The systematic use of the announcement that the stimuli that will be presented will differ across the two partner-participants was therefore efficient.[5]

The ERP differences found were obtained in conditions similar to those of the first two studies [20 & 21]. Namely, partner-participants were close others. They were thus people whose brain had already been exposed to the vwMFesf of their partner. This suggests that the sensitivity to vwMFesf is very specific, which is confirmed by the dependence of ERPs on subtle differences. Namely, on the differences that exist between the color front view of two faces. This means that the vwMFesf produced by the brain of a person who is processing a stimulus are specific of that stimulus, in addition to being specific of the person.[6] It also means that the brain of close others can detect these specificities.

The results open a new avenue of research in physics as well as in cognitive neuroscience. Indeed, finding how the brain is capturing vwMFesf might allow the creation of new devices. Finding how the brain captures their specificity and richness while removing electromagnetic noise might yet be another challenge for physicists. But it could be worth it. It would lead to completely new brain-computer interfaces [31], for instance.

For cognitive neuroscience, some of the new avenues of research opened have already been mentioned in the two previous studies [20 & 21]. The present results can be used to support field theories of consciousness [14-19]. However, it has to be pointed out again that they might never be used for planned human communications. Indeed, participants appeared to be totally unaware that the activity of their own brain depended on that of their partner. The experimental design led to no insights pertaining to what the partner was presented with and to what (s)he was feeling or thinking. This is surprising as the late ERP modulations found suggest that the information gathered through the vwMFesf sensitivity was then processed at a high level. In effect, it depended on the subtle facial features that code the identity of a face. These findings thus further those reported in Wang et al. [12] who showed the development of strategies of use of the information gathered through the sensitivity of the human brain to the (geo)magnetic field. In any case, further experiments have to be run to be able to discuss the functional significance of the impacts of stimulus processing on the brain activity of others.

Author Contributions: Conceptualization, J.B.D. methodology, J.B.D.; software, M. L. & É. J. validation, É. J.; formal analysis, É. J. & F. J.; investigation, É. J., M. L. & F. J.; resources, J.B.D. data curation, É. J., M. L. & F. J.; writing—original draft preparation, J. B. D. writing—review and editing, J.B.D. É. J., & M. B.; visualization, É. J.; supervision, J.B.D.; project administration, J.B.D.; funding acquisition, J.B.D. All authors have read and agreed to the published version of the manuscript."

Funding: This study was supported by grant 194517-03 from the Natural Sciences and engineering Council of Canada (NSERC) allocated to J. B. Debruille.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Research Ethics Board of the Douglas Mental Health Research Institute (Douglas REB #12/12)."

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data and Method Availability Statement: All data, including raw EEG files (in a Matlab format), and the way they have been processed (including the software codes) will be placed at Mendeley data (Debruille, Bruno (2022), "JointProcessingEffects15", Mendeley Data, V1, doi: 10.17632/fwsmdr4hvy.1). As mentioned, the data of the two previous studies [20 & 21] have been reprocessed to more accurately identify the circumstances in which the effects occur. Four additional factors were found. They have been used systematically in the present study. They have been declared at the office of innovation of McGill university (disclosure **ROI 2022-117**). These factors of the method will be copyrighted and made accessible to those who accept to cite the present paper. Those who want to use these factors for clinical trials, for creating new devices or for any purpose that may end-up producing a financial profit will have to go to a transactional website[1] and pay a fee, in addition to having to cite the present paper.

Acknowledgments:

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results".

Note section

[1] as hypothesized by field theories of consciousness [e. g., 14-19].

[2] as hypothesized by [20, 21], to account for the ability of the brain at producing percepts similar to those of others.

[3] In effect, their argument against a magnetic field explanation of the effects they found and their defense of a quantum mechanism is based on a difference between the two phenomena that is inappropriate (see [8] for instance).

[4] announcing that the partner's stimuli will be different from the ones participants are presented with makes these participants think that they cannot have an idea of what their partner is looking at. It thus prevents them from consciously trying to guess what the stimulus is making them feel and think. In other words, it prevents the development of brain activities corresponding to the so-called mentalization processes, which are consciously controlled processes [e. g., 22]. The different announcement thus favors more spontaneous brain activities. Getting more robust results with this announcement thus gives an indication about the activity state during which the brain is more sensitive to the vwMFelf produced by others.

[5] Further details about the methods used can be found in the web site indicated in the Data and Methods Availability Statement above.

[6] This double specificity fits the characteristics of the conscious perception of a stimulus. When we are seeing something, we are also conscious that it is us who are seing it. The representation of the stimulus is bound to the representation of the self [29, 30])

References

1. Yeagley H.L. A preliminary study of a physical basis of bird navigation. J. of Appl. Physics 1947, 18, 1035-63.
2. Kalmijn, A.J. Biophysics of geomagnetic field detection. *Ieee transactions on magnetics* 1981, 17, 1113-24.
3. Rosenblum B.: Jungerman R.L.; Longfellow L. Limits to induction-based magnetoreception. In *Magnetite Biomineralization and Magnetoreception in Organisms: A New Biomagnetism,* Kirschvink J. L., Jones D. S., MacFadden B. J., Eds, New York: Plenum Press 1985, pp 223-232.
4. Schulten K. Magnetic-Field Effects in Chemistry and Biology. Festkorperprobleme- *Advances in Solid State Physics* 1982, 22, 61-83.
5. Ritz, T.; Adem, S.; Schulten, K. A model for photoreceptor-based magnetoreception in birds. *Biophys. J.* 2000, 78, 707-718.
6. Hore, P. J.; Mouritsen, H. The Radical-Pair Mechanism of Magnetoreception. In *Ann. Rev. of Biophys.* 2016, Vol 45 (Dill KA, ed), pp 299-344. 2016
7. Kirschvink J. L.; Gould J. L. Biogenic magnetite as a basis for magnetic field sensitivity in animals. *Bio Systems* 1981, 13, 181-201.
8. Binhi, V. N., & Prato, F. S. Rotations of macromolecules affect nonspecific biological responses to magnetic fields. *Scientific reports* 2018, *8*(1), 1-11.
9. Kerwin, L. J.; Keller, C. J.; Wu, W.; Narayan, M., & Etkin, A test-retest reliability of transcranial magnetic stimulation EEG evoked potentials. *Brain stimulation* 2018, 11(3), 536-544.
10. Pellegrini, M.; Zoghi, M., & Jaberzadeh, S. The effect of transcranial magnetic stimulation test intensity on the amplitude, variability and reliability of motor evoked potentials. *Brain Res.* 2018, 1700, 190-198.
11. Noda, Y. Toward the establishment of neurophysiological indicators for neuropsychiatric disorders using transcranial magnetic stimulation-evoked potentials: A systematic review. *Psychiat. & Clin. Neurosci.* 2020, 74(1), 12-34.
12. Wang, C.X.; Hilburn, I.A.; Wu, D.A.; Mizuhara, Y.; Cousté, C.P.; Abrahams, J.N.; ... & Kirschvink, J. L. Transduction of the geomagnetic field as evidenced from alpha-band activity in the human brain. *Eneuro.* 2019.
13. Hämäläinen, M.; Hari, R.; Ilmoniemi, R.J.; Knuutila, J.; & Lounasmaa, O.V.. Magnetoencephalography—theory, instrumentation, and applications to noninvasive studies of the working human brain. *Rev. of mod. Phys.* 1993, 65(2), 413.
14. Fingelkurts, A.A.; Fingelkurts, A.A.; & Neves, C.F. Natural world physical, brain operational, and mind phenomenal space–time. *Physics of Life Reviews* 2010, 7(2), 195-249. doi: 10.1016/j.plrev.2010.04.001
15. Hagelin, J. S. Is consciousness the unified field?: A field theorist's perspective. *Fairfield, IA: Maharishi International University* 1987, pp. 29-87.
16. Libet, B. A testable field theory of mind-brain interaction. *J. of Conscious. Studies* 1994, 1(1), 119-126.
17. McFadden, J. Integrating information in the brain's EM field: the cemi field theory of consciousness. *Neuroscience of consciousness* 2020(1), niaa016 doi: 10.1093/nc/niaa016
18. Pockett, S. The nature of consciousness: A hypothesis. *IUniverse 2000.*
19. Pockett, S. Difficulties with the electromagnetic field theory of consciousness. *J. of Conscious. Studies* 2002, 9(4), 51-56. doi: 10.14704/nq.2007.5.3.136
20. Bouten, S.; Pantecouteau, H.; & Debruille, J.B. Qualia as social effects of mind. *F1000Research* 2014, 1. doi.org/10.12688/f1000research.5977.1
21. Haffar, M.; Pantecouteau, H.; Bouten, S.; & Debruille, J.B. Effects of Stimulus Processing on Event-Related Brain Potentials of Close Others. *Preprints* 2018, 2018060084 (doi: 10.20944/preprints201806.0084.v1).
22. Bull, R.; Phillips, L.H., & Conway, C.A. The role of control functions in mentalizing: Dual-task studies of theory of mind and executive function. *Cognition* 2008, *107*(2), 663-672.
23. Mendelson, M.J., & Aboud, F.E. Measuring friendship quality in late adolescents and young adults: McGill Friendship Questionnaires. *Canadian J. of Behav. Sci./Revue canadienne des sciences du comportement* 1999, *31*(2), 130.
24. Debruille, J.B., Brodeur, M. B., & Hess, U. Assessing the way people look to judge their intentions. *Emotion* 2011, *11*(3), 533.
25. Tecce, J. J. Contingent negative variation (CNV) and psychological processes in man. *Psychological Bulletin 1972*, *77*(2), 73–108. doi:10.1037/h0032177
26. Electrode Position Nomenclature Committee. Guideline thirteen: guidelines for standard electrode position nomenclature. *J. Clin. Neurophysiol 1994*, *11*, 111-113.
27. Greenhouse, S.W., & Geisser, S. On methods in the analysis of profile data. *Psychometrika 1959*, *24*(2), 95-112.
28. Benjamini, Y., & Hochberg, Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal statistical society: series B (Methodological) 1995*, *57*(1), 289-300.
29. Spanlang, B.; Nierula, B.; Haffar, M.; & Debruille, J. . Mimicking schizophrenia: Reducing P300b by minimally fragmenting healthy participants' selves using immersive virtual reality embodiment. *Frontiers in Human Neuroscience* 2019, 504. doi.org/10.3389/fnhum.2018.00504
30. Thompson, E., & Varela, F. J. Radical embodiment: neural dynamics and consciousness. *Trends in Cognitive Science* 2001, 5, 418–425. doi: 10.1016/s1364-6613(00)01750-2

 doi:10.20944/preprints202207.0120.v1

31. Lawhern, V.J.; Solon, A.J.; Waytowich, N.R.; Gordon, S.M.; Hung, C.P. & Lance, B. J. EEGNet: a compact convolutional neural network for EEG-based brain–computer interfaces. *J. of neural engineering* 2018, 15(5), 056013.