



RESEARCH ARTICLE

REVISED Looking for effects of qualia on event-related brain potentials of close others in search for a cause of the similarity of qualia assumed across individuals [version 3; referees: 2 approved]

Previously titled: Finding indexes of spontaneous brain-to-brain communications when looking for a cause of the similarity of qualia assumed across individuals

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Abstract

Qualia, the individual instances of subjective conscious experience, are private events. However, in everyday life, we assume qualia of others and their perceptual worlds, to be similar to ours. One way this similarity is possible is if qualia of others somehow contribute to the production of qualia by our own brain and vice versa. To test this hypothesis, we focused on the mean voltages of event-related potentials (ERPs) in the time-window of the P600 component, whose amplitude correlates positively with conscious awareness. These ERPs were elicited by images of the international affective picture system in 16 pairs of friends, siblings or couples going side by side through hyperscanning without having to interact. Each of the 32 members of these 16 pairs faced one half of the screen and could not see what the other member was presented with on the other half. One stimulus occurred on each half simultaneously. The sameness of these stimulus pairs was manipulated as well as the participants' belief in that sameness by telling subjects' pairs that they were going to be presented with the same stimuli in two blocks and with different ones in the two others. ERPs were more positive at all electrode subsets for stimulus pairs that were *inconsistent* with the belief than for those that were consistent. In the N400 time window, at frontal electrode sites, ERPs were again more positive for inconsistent than for consistent stimuli. As participants had no way to see the stimulus their partner was presented with and thus no way to detect inconsistency, these data might reveal an impact of the qualia of a person on the brain activity of another. Such impact could provide a research avenue when trying to explain the similarity of qualia across individuals.

Keywords

Really direct brain-to-brain communications, Mind-to-mind Qualia, Consciousness, Event-related brain potentials (ERPs), P3b-P600, IAPS stimuli

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REVISED Amendments from Version 2

We have changed the title of the paper to indicate the main goal of the study with more precision. We also, from the beginning of the intro, specify that we are talking of the similarity of qualia, not of identical qualia across individuals.

See referee reports

Introduction

Colors, sounds and smells do not exist in the outside world. They are the creations of our brain in response to light waves, rhythmic variations of air pressure and inhaled molecules, respectively. External stimulations are responsible for action potentials in the brain whose processing may then produce colors, sounds and smells. These, so-called qualia^{1,2} are then apparently projected outside around us and constitute our perceptual world, sometimes called the phenomenal world³. Although perceived internally, except in the case of out-of-body experiences⁴, events, such as feelings of meanings, as in the tip of the tongue phenomenon, or such as emotions, conscious intentions to act and sensations of our body can also be seen as qualia.

Understanding consciousness as consisting of self made qualia leads to one of the most enduring philosophical questions: Are qualia similar across individuals? In other words, is the yellow produced by the brain of one person similar to the yellow produced by the brain of another person? Surprisingly, there is no way to know for sure. The fact that the same word is used by all the people speaking a language to designate a qualia merely establishes a correspondence. It does not prevent the qualia it indicates from varying across these people. The yellow qualia for one person could, for instance, be the blue qualia for another person. Nevertheless, such differences across individuals appear unlikely since many use the same associations and agree that red is a warm color and that blue relates to sadness. In the auditory modality, many associate high pitch sounds with sharpness. Moreover, we use the same metaphor and define these sounds as “high” whereas those of longer wavelengths are said to be “low” sounds (for other metaphors see for instance Lakoff and Johnson⁵). The same relations between qualia thus appear to exist across people whereas if qualia were different across individuals it seems that these relations should also differ. It could, nevertheless, be argued that metaphors used in a language convey relationships between certain qualia and are thus responsible for building the links between them. However, a number of new metaphors can be understood at their first occurrence⁶, which suggests that relations between qualia are, at least partly, independent of language.

In any case, if the qualia produced by our brains in response to a given stimulus were not similar across individuals, one could call the entire human race delusional since we all go through our everyday lives and interact with others as if they perceive the world in pretty much the same way as we do. As a matter of fact, if the phenomenal world of each individual were unique, the most fundamental social consensus would be lost. Sharing feelings by verbalizing emotions would be an illusion and our use of language as if each word designates the same qualia would be incorrect. It thus appears

reasonable to hypothesize that qualia are similar across individuals and that we are actually living in similar phenomenal worlds.

At first sight, it is tempting to say that qualia could be similar because of the resemblances existing between the brains of humans. However, this idea is questionable for several reasons. First, when macroscopically comparing the brain of people, one can be stricken by the large differences existing between their shapes (with some extreme, such as the one described by Feuillet *et al.*⁷). There are also problems at the microscopic level. For instance, nothing has been found that distinguishes the so-called color-cells of V1 for blue from the V1 color cells for yellow apart from their afferences⁸. Thus, applied within a person, the neuronal similarity argument would predict that qualia for blue should be similar to the qualia for red or yellow. Another point can be made with the qualia for white, which is generated by the stimulation of the three types of cone cells, or even by only two complementary colors (e.g., green and red, which stimulate the M and the L cone cells or blue and yellow). How could the V1 « color cells », which are processing the output of these cone cells generate the same qualia? There again, similarities between particular neurons and qualia do not work. So the hypothesis of a similarity of qualia creates a problem. How could qualia be similar across individuals when they are said to be, by nature, totally private events not strictly dependent on brain similarities?

Another, apparently unrelated, question is: how can qualia within a given person be so qualitatively different from one another while theoretically originating from the same type of neuronal bioelectrical activity? Sounds appear to be totally orthogonal to colors or smells. Nevertheless, they are induced by the same depolarizations, such as those induced by Penfield and Jasper⁹ at different places of the cortex. One way to address this issue is to hypothesize that, while dependent on the well-known bioelectrical activities of neurons, the physical nature of qualia is not limited to these activities. The authors of this second hypothesis can grossly be divided into those suggesting, (a) that qualia are also electromagnetic fields (for a recent review, see Jones¹⁰) and (b) those developing the even more controverted theory that qualia also include modulations of the wave function described by quantum mechanics (e.g., 11). Each of these two theories thus introduces phenomena, which, by the immense variety of the instances they include, could provide ways to account for the qualitative differences existing between percepts.

Interestingly, thinking about qualia in terms of electromagnetic fields or in terms of modulations of the wave function could also provide a hint as to how qualia are apparently projected to form our perceived environment and also how they could be similar across individuals while being “private events”. Indeed, both physical phenomena propagate. They can thus be projected and travel between individuals. Therefore, some kind of inter-subjective sharing could theoretically occur. In other words, experiencing a qualia might have an impact on the qualia of another person. This means that, at least in some conditions, the brain activity of a person might be influenced by the activity of the brain of another person. However, to the best of our knowledge, no study has yet *reliably* reported direct and natural brain-to-brain communications. The only report¹² we know of did not pertain to spontaneous phenomena either.

Testing this possibility was the first aim of the present study. To achieve this goal, we focused on one operational hypothesis: the event-related brain potentials elicited by a stimulus in one person, particularly the P600, could depend on the stimulus displayed to another person. This P600 is a late event-related brain potential (ERP) elicited by the presentation of meaningful stimuli, such as, words, objects, faces and scenes. It belongs to the P3b family of components despite its late maximum, which occurs around 600 ms post stimulus onset when using complex stimuli such as words, objects, faces and even a little later when using scenes. The greater the amount of new information placed in working memory, the larger the amplitude of this potential^{13,14}. When a stimulus is unexpected, or when any of its aspects (e.g., its exact time of occurrence) are unpredicted, it elicits a larger P3b-P600 than when the stimulus and every of its aspects are fully predicted. A very large number of cognitive factors can have an impact on the amplitude of the P3b-P600 (see in 14 for the P3b and in 15 for the P600). Thus, if new information was coming from the brain of another person and was having an impact on the activity of the brain of a subject, it might modulate the amplitude of this potential. For instance, if subjects believed that the other person was going to be presented with the same stimulus as them whereas the current information coming from the brain of that person is not consistent with this prior belief, there could be a need for some updating. Accordingly, the P3b-P600s might differ from the ones obtained in conditions in which the information coming from the brain of this other person is consistent with the prior belief.

Exploring pairs of participants and manipulating their beliefs allows the testing of this operational hypothesis. In the present study, a statement announced the two participants of each of these pairs whether or not they would be simultaneously presented with the same stimulus at the beginning of each of the 4 stimulus blocks that were used. These two statements were true in two blocks and false in the two others. If some specific information could pass from the brain of a participant to the brain of the other member of the pair and if this information is not consistent with the belief created by the block statement, it might induce an updating and modulate P3b-P600s. If this were the case, then the existence of direct and spontaneous brain-to-brain communications would be demonstrated if, and only if, that there is no way for participants to see the stimulus the other person is presented with and thus no way to know whether it is consistent with the statement or not.

The second aim of the study had no relation whatsoever to the exploration of the causes of the assumed similarity of qualia across individuals. It was totally separate from the possibility of an impact of one's activity on the brain of another person. This second goal was to evaluate the impact of social cognition on memory. Indeed, having a mental representation of a partner going through an event (i.e., the presentation of a stimulus), in addition to having a representation of oneself going through the same event, might enrich the encoding in episodic memory and facilitate delayed recognition. Thus, subjects were told to remember each image because there would be a memory test at the end. Our second operational hypothesis was that they would have a higher rate of recognition for the stimuli they were presented with when they *believed* they were seeing the same stimuli as their friend and a lower rate of recognition for the other stimuli. There were thus two independent

experimental variables in the present study, consistency for the first (i.e., the brain-to-brain) hypothesis and belief for this second social cognition hypothesis.

Method

Participants

Thirty-two right-handed participants (25 F, 7 M), pairs of friends, couples, or siblings were recruited because it was assumed, for this first attempt, that testing people in a close relationship could only increase the odds of natural brain-to-brain communications. The 32 subjects of the 16 pairs underwent exactly the same procedure. All participants learned about the experiment through classified ad websites. They spoke fluent English, were between eighteen and thirty years of age (mean = 23.1, SD = 3.4) and had completed, or were in the process of completing, a university degree. They had normal or glasses-corrected to normal vision. Participants were excluded if they consumed more than twelve drinks of alcoholic beverages per week or if they used recreational drugs, except if they used marijuana less than once per week. Participants were also excluded if they had a history of psychiatric disorder, took medication related to such a disorder, or if one of their first degree relatives had a history of schizophrenia or bipolar disorder. All these inclusion- and exclusion-criteria were checked by an eligibility questionnaire.

Consent

The two participants of each pair came to the lab together for approximately three hours. Each participant read and signed an informed consent form accepted by the Douglas Institute Research and Ethics Board, which focused on the second aim. This board, which follows the principles expressed in the declaration of Helsinki, also approved the experiment (Douglas REB #12/12). Data were anonymized, which did not distort scientific meaning.

Stimuli

Stimuli were images selected from the International Affective Picture System (IAPS, 16). Using our own judgment, we chose 560 pictures of this set, including many striking ones, to ensure the maintenance of participants' attention during the tasks. The experiment consisted first of the study phase, which included four blocks, and then of a memory test phase. As presented in Table 1, which explains their acronyms, each of the four blocks of the study phase, DBd, SBs, Sbd and DBs, corresponded to a particular sameness and belief condition. The order of presentation of these four blocks was randomized across subject pairs using a Latin square. We used four different sets of 70 IAPS stimuli. The allocation of each set to each block was also randomized across subject pairs. In study phase blocks in which different pictures were seen by each member of a pair (i.e., in the DBd and DBs blocks), the picture set seen by one participant in DBd was seen by the other participant in DBs, and vice versa. Therefore, all pictures of the four sets were seen by both participants during the study phase. The memory test phase consisted of a fifth set of pictures that contained, in a random order, all the pictures of the study phase mixed with 280 additional pictures.

Procedure

The study phase (Table 1) was followed by the memory test phase. As illustrated by Figure 1B, each stimulus of the study phase was

Table 1. Study phase conditions.

Name of study phase condition (acronym). Consistency.	Statements (between quotes) seen simultaneously by the two members of each pair on their own half of the screen before each block-condition of the study phase and what reality was.
Different Believe-different (DBd). Consistent.	"Try to remember the next 70 pictures. You will now see different pictures than your friend," and they did see different images.
Same Believe-same (SBs). Consistent.	"Try to remember the next 70 pictures. You will see the same pictures as your friend," and they did see the same pictures.
Same Believe-different (SBd). Inconsistent.	"Try to remember the next 70 pictures. You will see different pictures than your friend," but they saw the same pictures.
Different Believe-same (DBs). Inconsistent.	"Try to remember the next 70 pictures. You will see the same pictures as your friend," but they saw different pictures.

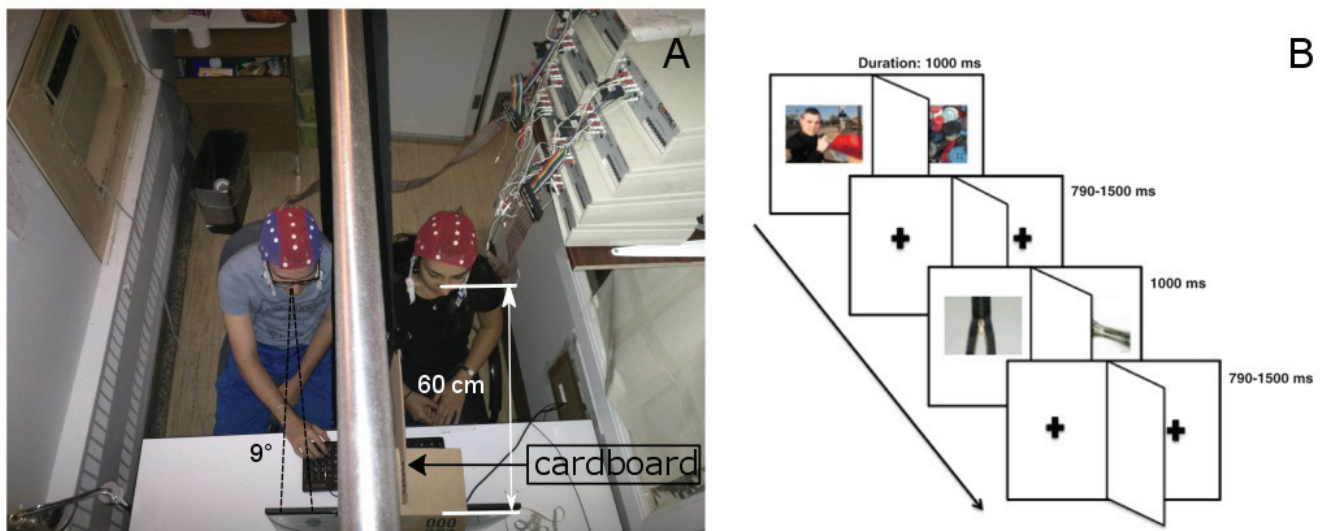


Figure 1. A. Experimental setup. Note that the black "cardboard" arrow is above a beige horizontal rectangle. This rectangle is a piece of cardboard whose rear edge is stuck on the upper edge of the computer screen. It includes a notch within which is inserted the vertical piece of cardboard that separates this computer screen into two halves. This prevents participants from seeing the stimulus presented to his/her partner. The tip of the black arrow coincides with that vertical piece. The "9°" indicate the visual angle encompassed by the stimulus presented to each partner, whose eyes are about 60 cm from the computer screen. **B.** IAPS stimulus presentations for each of the 4 conditions of the study phase. The different-and-believed-different (DBs) condition is used as an example. Note again the division of the screen into two halves by a vertical cardboard piece, preventing subjects from seeing each other's stimuli, but not from feeling close to one another.

presented for 1000 ms and was followed by a white screen with a black fixation cross, the duration of which randomly varied between 790 and 1500 ms to prevent the development of a contingent negative variation¹⁷. Participants could see their partner in their very peripheral vision field without moving their eyes. Nevertheless, even if they moved their eye or move their heads they could not see the part of the screen their partner was watching (Figure 1A illustrates this unusual setting). Participants were told to look at each picture for the subsequent memory test phase. Stimuli in that latter phase were presented for 3000 ms in order to allow time for participants to respond.

During the memory test phase, participants were required to respond by pressing keys on a *shared* computer keyboard. The participant seated on the left hand side of the keyboard used the typewriter keys and pressed '1' to indicate (s)he believed to have

seen the picture previously, and '2' to indicate (s)he believed not to have seen the picture previously. The participant seated on the right hand side of the keyboard used the numeric keypad and pressed '4' to indicate (s)he believed to have seen the picture previously, and '5' to indicate (s)he believed not to have seen the picture previously.

At the end of the memory test phase, there was a debriefing session where participants were asked 4 questions, mainly designed to explore attention differences and whether they detected any deception. The first was: "Did you feel more attentive/distracted seeing the pictures when your friend was present?". The second was: "Did you feel any different when you knew your friend/partner/relative was looking at the same images that you were seeing? ». The third was: « Did you feel any different when you knew your friend/partner/relative was looking at different images than you

were seeing? ». The fourth was: « Did you feel deceived at any point during the experiment? ».

Data acquisition

Behavioral key presses were recorded during the memory test phase, as well as the verbatim of the response to the debriefing session's questions. The electro-encephalogram was recorded from 28 electrodes mounted in an elastic cap (Electro-Cap International) during the study phase. Electrodes were placed according to the modified expanded 10–20 system¹⁸. For each participant of each pair, these electrodes were grouped into three subsets: sagittal (Fz, Fcz, Cz and Pz), parasagittal (F3/4, Fc3/4, C3/4, Cp3/4, P3/4, and O1/2), and lateral (F7/8, Ft7/8, T3/4, Tp7/8 and T5/6). There was a separate set of amplifiers for each participant. The right earlobe was used in each subject as the reference for his/her set of amplifiers while the ground was taken from an electrode two centimeters ahead of Fz. For both sets of amplifiers, high- and low-pass filter half-amplitude cut-offs were set at 0.01 and 100 Hz, respectively, using an additional 60 Hz electronic notch filter. EEG signals were amplified 10,000 times and digitized online at a 256 Hz sampling rate and stored in a single file with 56 (28 × 2) channels.

Data processing and measures

In each trial, electrodes contaminated by eye movements, excessive myogram, amplifier saturations or analog to digital clipping were removed offline by setting automatic rejection criteria. Electrodes for which analog to digital clipping exceeded a 100 ms duration and electrodes for which amplitude exceeded +/- 100 mV were discarded when these excesses were within the -200 to +1000 ms. The baseline was set prior to the onset of the stimulus, from -200 to 0 ms. Averages were calculated for each block and each subject in a 1400 ms time window, beginning 200 ms before the onset of the stimulus and lasting for 1200 ms after the stimulus onset. Following averaging, each file was divided into two files, each containing the ERPs of a single subject. The ERPs of each of the 32 subjects for each consistency-with-belief condition (consistent vs. inconsistent) and each belief condition (belief-same vs. belief-different) were then computed and measured independently of the pair of participants they initially belong to. Based on our a priori hypothesis, we focused on the late positive component (LPC or P600) and computed the mean voltages of ERPs in the 650–950 ms time window for all electrodes, all subjects and all four conditions. Nevertheless, because visual inspection detected a small difference in the time window of the potential that preceded the P600, that is, the N400, mean voltages were also measured in the 350–550 ms time window to explore these differences and create a priori hypotheses for future studies.

Analyses

Repeated-measures ANOVAs were run with the version 20 of the IBM-SPSS software package to analyze these measures using a multivariate approach. For the sagittal subset of electrodes, they had consistency of the actual stimuli with the belief (consistent vs. inconsistent) or social cognition (belief that stimuli were the same vs. belief they differed) and electrodes as within-subject factors. For parasagittal and lateral electrodes, a fourth within-subject factor, hemiscalp (right vs left), was included. Given that there was only one group of 32 subjects, there was not any between-subject factor. The Greenhouse and Geisser¹⁹ procedure was used when

required to compensate for heterogeneous variances, in which case the original F values and the corrected p values will be given. To provide a priori hypotheses for future studies, we also completed one-way ANOVAs at each electrode to assess each effect found.

Results

Electrophysiological results: Testing the first hypothesis of natural brain-to-brain communications

Figure 2 shows the grand averages for the 32 subjects of the 16 pairs tested. Visual inspection of the P600 time window at the electrodes where the amplitude of this ERP component is usually maximal, that is, at the central (Cz) and parietal (Pz) midline sites, suggests slightly larger P600s when pairs of stimuli were inconsistent with the prior belief (red lines) than when they were consistent (black lines). At frontal electrode sites, ERPs were also slightly more positive for inconsistent- than for consistent-stimuli in the time window of the potential that precedes the P600, that is, the N400. Social cognition in itself (Figure 3) was found to correspond to some small ERPs differences, mainly located at left anterior lateral electrode sites (i.e., F7 & Ft7). There, the prior belief that stimuli seen by the other member of the pair were different from the ones seen by the participant goes with ERPs (black lines) that seem a bit less positive than the ERPs elicited by stimuli of the two blocks preceded by the statement mentioning that the same stimuli will be presented to the two participants (blue lines).

Table 2 includes the significant ($p < .05$) effects found in the ANOVAs performed on each subset of electrodes in the time-window of the P600. It reveals that the effect of consistency was significant at each electrode subset.

In addition, as mentioned, visual inspection of the ERPs according to consistency (Figure 2) revealed small differences within a time windows preceding that of the P600 (e.g., at Fz). Exploratory ANOVAs were thus run to test the significance of these differences within the 350–550 ms.time window. Consistency was found to interact with electrodes at the sagittal subset of electrodes ($F(3-93) = 3.93, p = .029$), as illustrated by Figure 4. The post hoc analysis performed at Fz to locate the source of this interaction confirmed the significance of this effect at this frontal sagittal site ($F(1-31) = 7.94, p = .008$), which is reported here to create a priori hypotheses for future studies, as there was no relation with a priori hypotheses. No main effects of, or interaction with, consistency was found for the two other electrode sets.

The replicability of these findings was explored by computing grand averages of the 16 subjects who had their partner on their right side and those who had their partner on their left side. Note that these two sets of subjects went through the exact same procedure and conditions except that each of them was hooked up to a particular set of amplifiers. Figure 5A and B display these grand averages. They bring support for replicability to the extent that 1) no difference was found in a direction that would be opposite to that observed in the grand average of the 32 participants and 2) ERPs appeared to be more positive for inconsistent than for consistent conditions in both groups during the P600 time window at

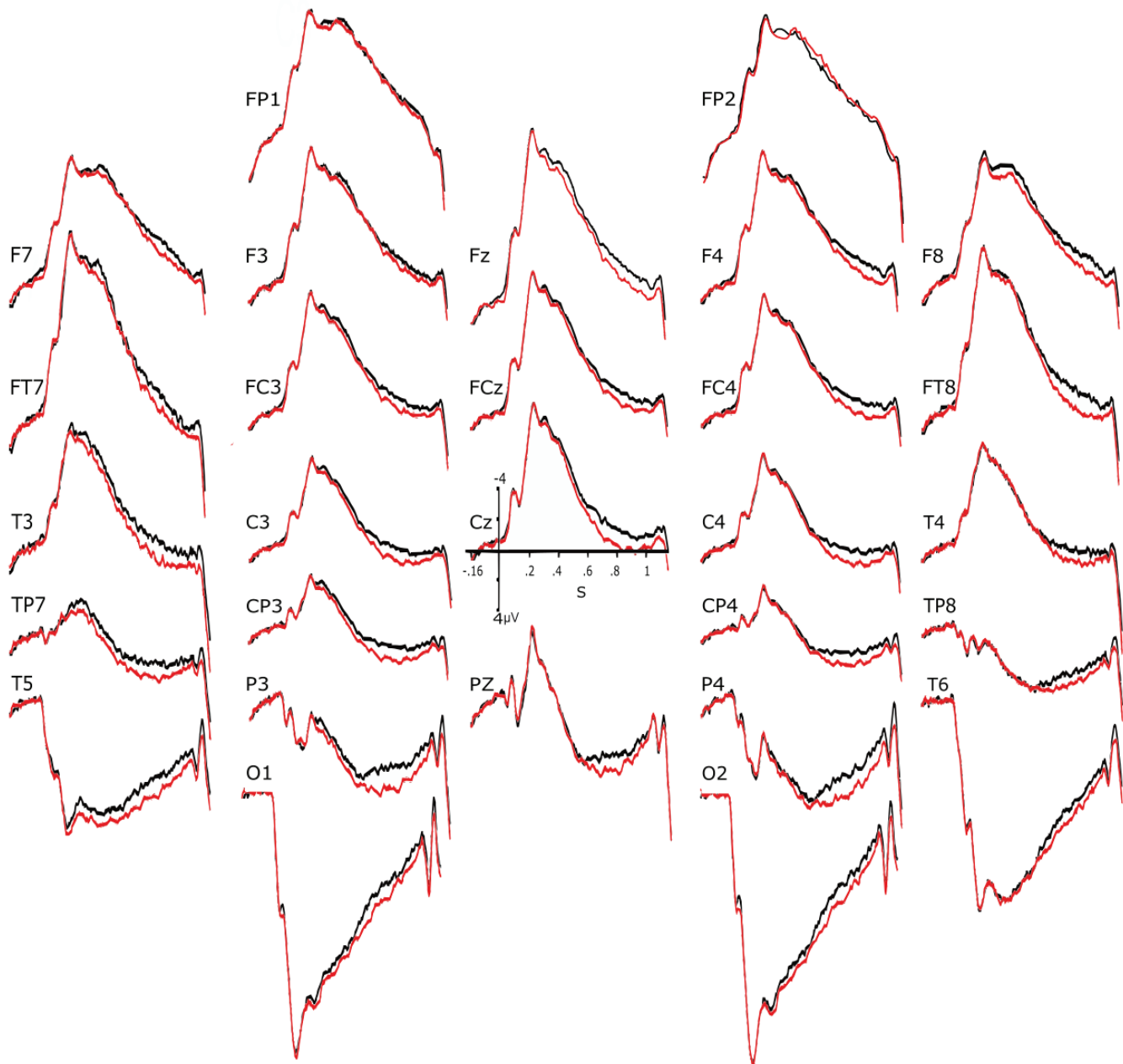


Figure 2. ERP effects of consistency Grand average ($n = 32$) of the event-related brain potentials elicited by the stimuli of the international affective picture system (IAPS). Black waveforms are for the stimulations (140 in each consistency condition) that were consistent with the belief of the participants. This includes the block-condition where the stimulus presented to one partner differed from the stimulus simultaneously presented to the other partner while these partners believed the two stimuli differed. It also includes the block-condition where the two stimuli were the same and believed to be the same. Red waveforms are for opposite stimulations (also 140 for each partner) where the actual sameness of the two stimuli was inconsistent with the participants' belief. The downward notch at the end of most tracings correspond to the off-effect (i.e., to the disappearance of the IAPS picture used as a stimulus), which might also be associated to a vertical eye movement artefact kept since 1000–1200 ms was a non-reject interval.

central, centro-parietal and parietal electrode sites. Nevertheless, it can be noted that, at frontal sites, these differences appeared to be present only in subjects who had their partner on their right side and that, within the N400 time window, these differences appeared to be restricted to this last subgroup.

Interestingly, these ERPs allow eliminating the possibility of horizontal eye movements that would have been aimed at looking at the partner. Indeed, this were the case, one would have seen differences maximal at F7/F8 between the two subgroups. This is not what the visual inspection of these two figures reveals.

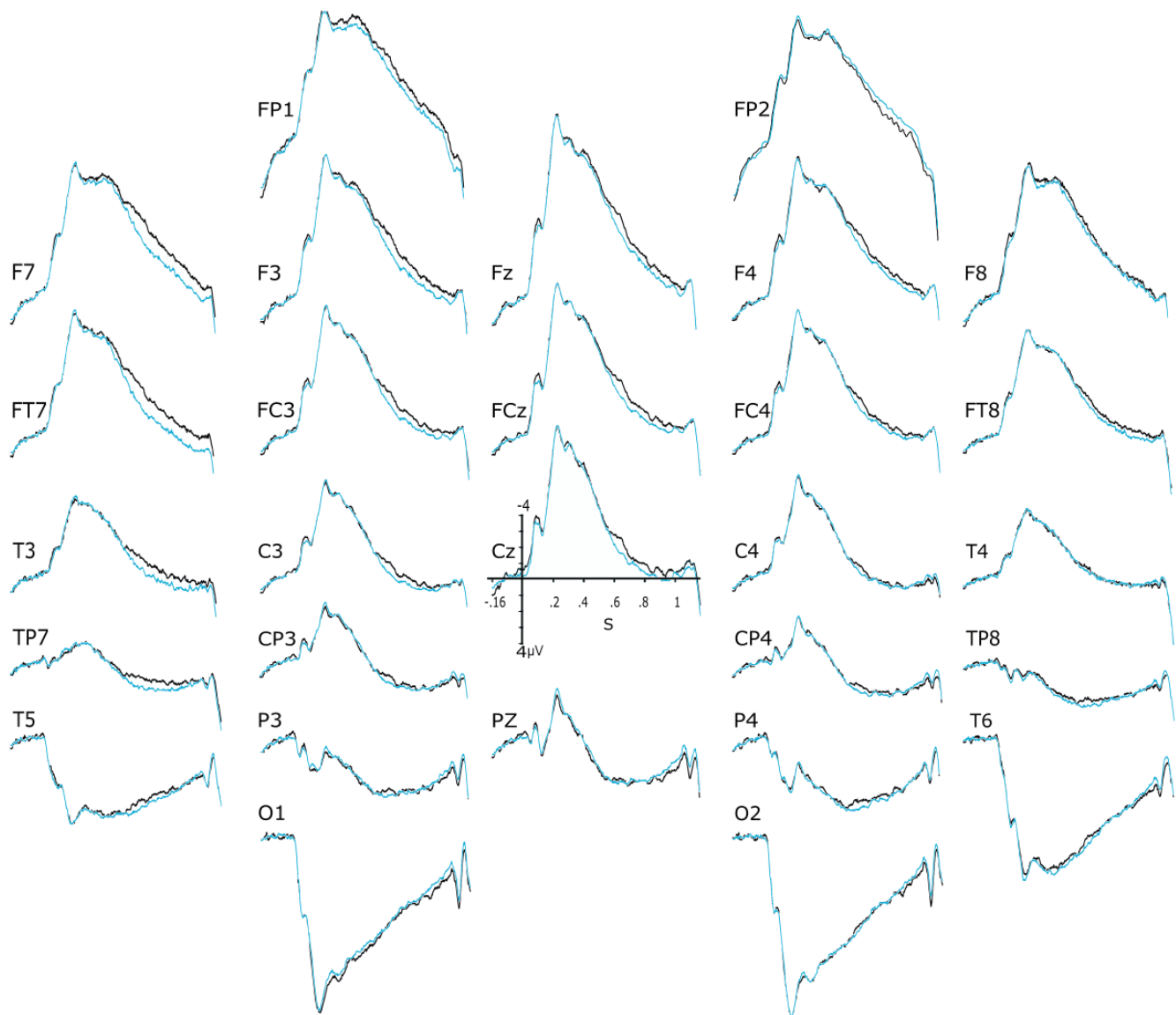


Figure 3. ERP effect of social cognition Grand average (n = 32) event-related brain potentials elicited by the stimuli of the international affective picture system (IAPS). Black waveforms are for an average of the two block-conditions where the participant believed (s)he was seeing stimuli (140 for each partner) different from the ones simultaneously presented to his/her partner. Blue waveforms are for an average of the two block-conditions where the participant believed (s)he was seeing the same stimuli (140 for each partner) as the ones simultaneously presented to his/her partner. The downward notch at the end of most tracings correspond to the off-effect (i.e., the disappearance of the IAPS picture used as a stimulus), which might also be associated to a vertical eye movement artefact kept since 1000–1200 ms was a non-reject interval.

Electrophysiological results: Testing the social cognition hypothesis

The ANOVA performed on each of the three electrode subsets with social cognition as factor revealed only a significant belief \times hemisphere interaction at the lateral subset ($F(1, 31) = 4.68, p = .038$). The post hoc run for the left hemisphere at this subset then showed a significant belief \times electrode interaction ($F(4, 124) = 3.25, p = .014$). To find the source of this interaction, a one-way ANOVA was run at F7, where

differences looked the “largest” on Figure 3. It confirmed the existence of a marginally significant effect ($F(1, 31) = 5.18, p = .030$).

Behavioral Results: Testing the social cognition effect on the encoding in episodic memory

As shown in Table 3, in the memory test phase, there was no difference between study phase conditions in the number of stimuli correctly recognized (hits) or in the number of misses. In sum,

Table 2. Statistically significant effects found in the three ANOVAs run with consistency, electrode and hemiscalp as factors in the P600 time windows (650–950 ms).

Electrode Subset	Factors	<i>F</i>	<i>p</i>
Sagittal	Consistency	8.73	.006
	Consistency × Electrode	3.36	.038
Posthoc at Cz	Consistency	10.61	.003
Parasagittal	Consistency	8.21	.007
Lateral	Consistency	7.49	.010

participants did not better recall images from any particular condition of the study phase. Similarly, there was no effect of the condition of the study phase on the reaction times of the memory test phase (Table 4).

The results of the debriefing session were as follows. For the question: “Did you feel more attentive/distracted seeing the pictures when your friend was present?”, 8 participants said they were more distracted, 18 said there was no difference, 6 said they were more attentive. To the question: “Did you feel any different when you knew your friend/partner/relative was looking at the same images that you were seeing?”, 17 participants said they felt the same, 14 said they felt different. To the question: “Did you feel any different when you knew your friend/partner/relative was looking at different images than you were seeing?”, 9 said yes, 22 said no. For the fourth question “Did you feel deceived at any point during the experiment?”, 27 said no, 3 misunderstood “deceived”, 2 said yes, but when asked why, they did not suspect the statements about the sameness of stimuli. Their suspicion pertained to other aspects (e.g., one said, after the stimulus presentation computer unexpectedly stopped, “I thought that when the computer crashed it was deliberately done so that it was more difficult to remember”).

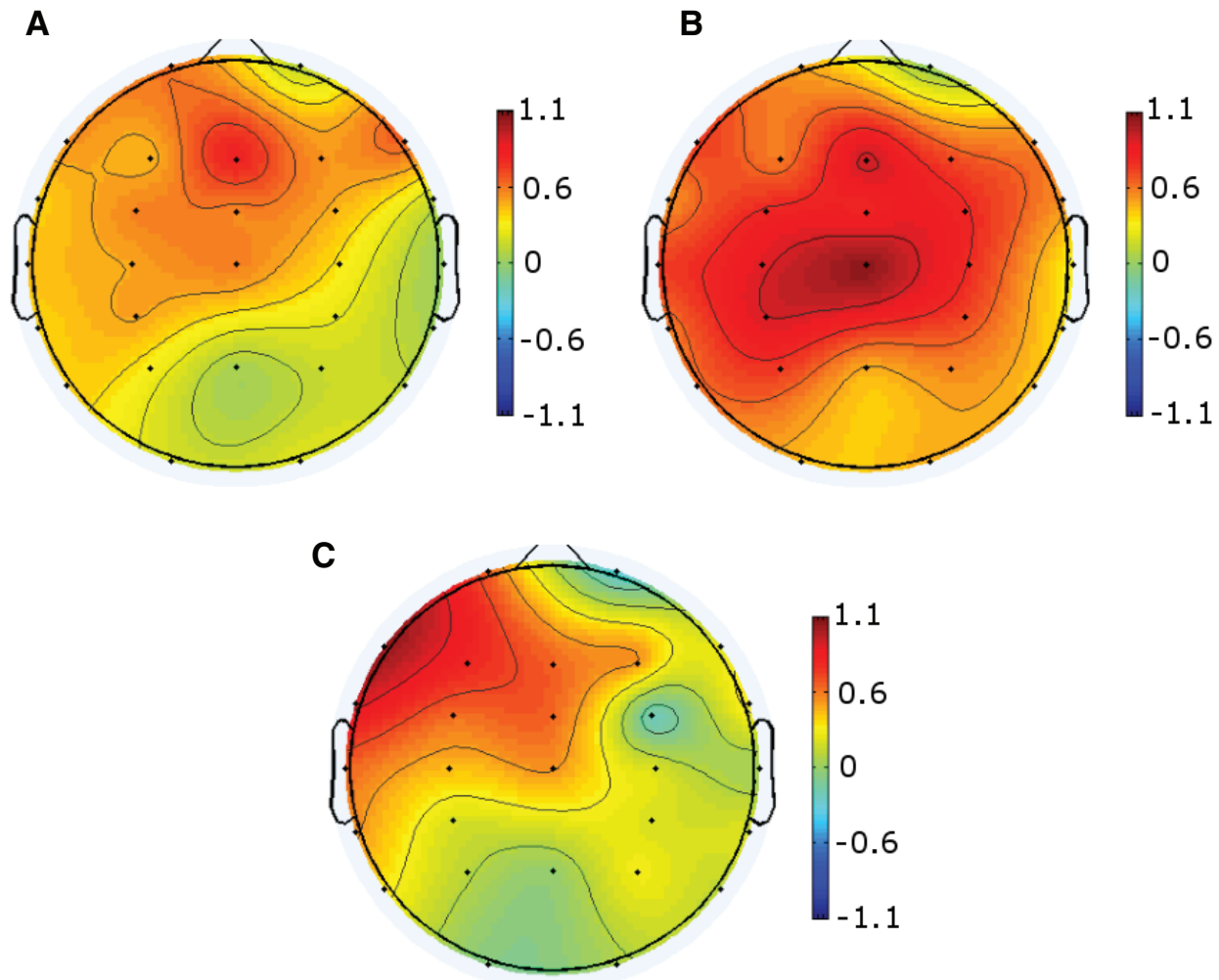


Figure 4. Maps of the ERP effects of consistency and belief. Spline interpolated isovoltage scalp maps computed after subtracting the mean voltages of the grand average ERPs **A**) in the N400 time window of the consistent conditions from the mean voltages of the inconsistent conditions, **B**) same as **A**) but for the P600 time windows, **C**) in the P600 time windows of the belief-different conditions from the belief-same conditions.

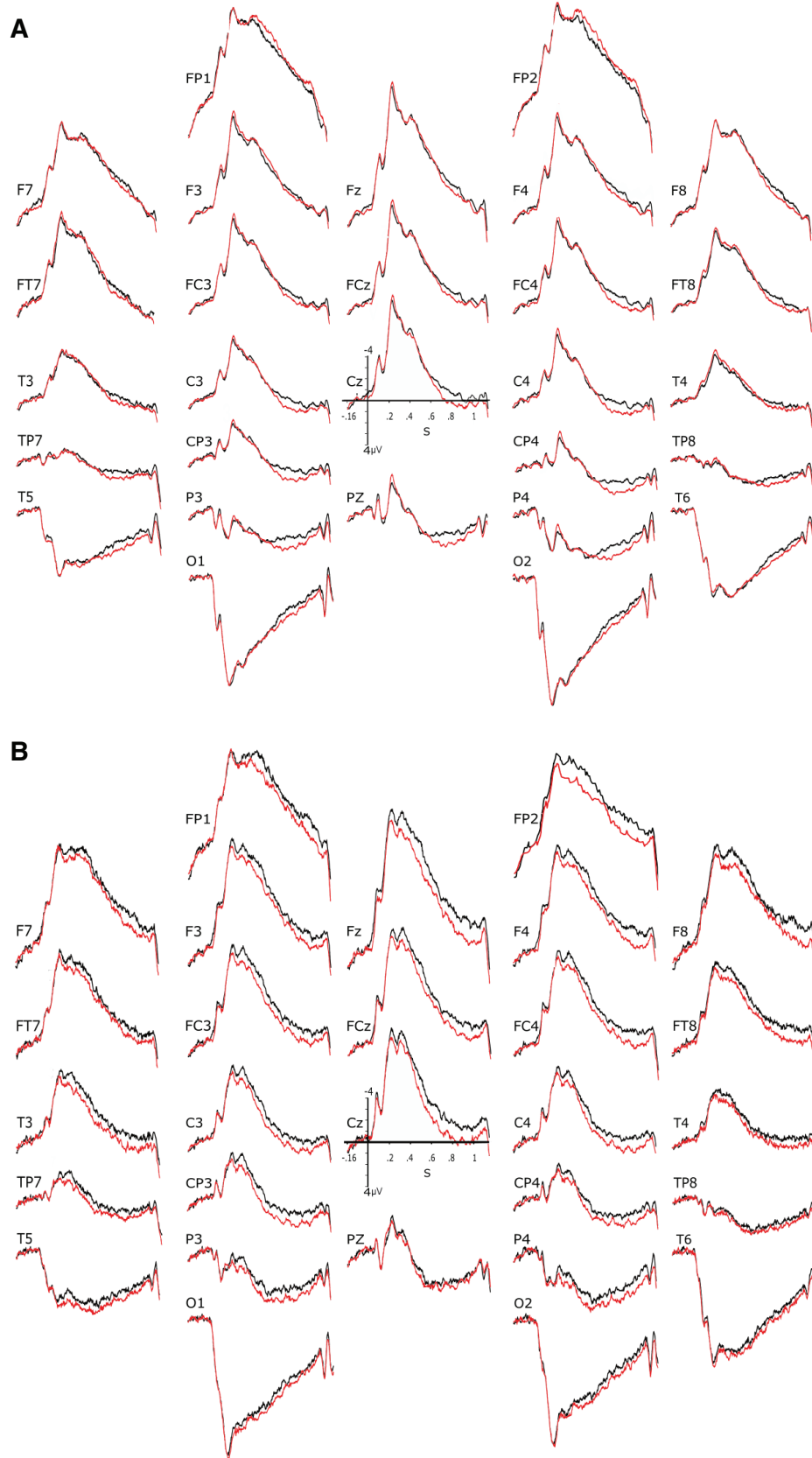


Figure 5. A) & B) Assessing replicability of consistency effects and eye movements towards the partner. Grand average of the event-related brain potentials (ERPs) of the two consistency conditions for the 16 participants who were on the right side of their partner. Colors as in Figure 2. **B)** same as **A)** but for the 16 participants who were on the left side of their partner. Colors as in Figure 2.

Table 3. Average number of hits versus misses by study phase condition.

Study Phase Condition	Number of Hits (SD)	Number of Misses (SD)
SBd	43.3 (10.1)	26.1 (9.7)
DBs	42.5 (10.9)	26.6 (11.1)
SBs	43.4 (12.3)	26.6 (12.2)
DBd	43.3 (10.9)	26.2 (10.8)

Table 4. Average reaction time of hits versus misses in milliseconds by study phase condition.

Study Phase Condition	Average Reaction Time of Hits in milliseconds (SD)	Average Reaction Time of Misses in milliseconds (SD)
SBd	1081 (125)	1185 (151)
DBs	1080 (135)	1138 (171)
SBs	1081 (125)	1157 (153)
DBd	1092 (133)	1146 (176)

Dataset 1. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the P600 time window

<http://dx.doi.org/10.5256/f1000research.5977.d100682>

This Excel file includes, in each cell, the mean voltage of the ERPs of one participant (lines: sub2 to sub38), for one electrode site (columns C3 to TP8) for consistent and inconsistent conditions.

Dataset 2. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the N400 time window

<http://dx.doi.org/10.5256/f1000research.5977.d100683>

Same as [dataset 1](#), but for the N400 time window.

Dataset 3. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the P600 time window for BS and BD conditions

<http://dx.doi.org/10.5256/f1000research.5977.d100684>

Same as [dataset 1](#), but for the conditions in which the participants believed (s)he was seeing the same stimulus as the one simultaneously presented to his/her partner (BS, for believe same) and for the conditions in which they believed it differed (BD, for believe different).

Discussion

In each recording session of this study, pairs of related participants were tested together. In each trial, two pictures taken from the international affective picture system (IAPS) were presented simultaneously, one for the first participant, the other for the second participant of the pair. All 32 participants of the 16 pairs tested were asked to remember these pictures during the four different blocks of

the study phase. These pictures were then presented again, mixed with new ones, during a subsequent memory test phase.

During both phases, the computer screen was divided in two halves that were separated by a vertical cardboard perpendicular to the screen. Each participant of a pair sat in front of one half of the screen and was presented with one picture at a time. There was no way for a participant to see the picture simultaneously presented to the other participant.

Sameness was manipulated. In two of the four conditions of the study phase, participants were presented with the same picture simultaneously (S conditions). They were presented with two different pictures in the two others conditions (D conditions). Social cognition was studied by manipulating the belief (B) pertaining to what the other member of the pair was presented with. Just before the beginning of each condition, or block, of the study phase, participants saw one of two statements on the screen, announcing whether or not the same picture would appear for both of them on each half of the screen. The four conditions of the study phase were thus: different believed-different (DBd), same believed-same (SBs), different believed-same (DBs) and same believed different (SBd), the latter two thus including statements that were inconsistent with reality.

Event-related brain potentials elicited by the IAPS pictures were recorded during these four conditions of the study phase to test our first hypothesis of natural and spontaneous brain-to-brain communications. In accordance with this hypothesis, ERPs were found to be more positive within the P600 time window in the inconsistent than in the consistent conditions at each of the three subsets of electrodes (e.g., sagittal, parasagittal and lateral). Note, however, that then, the independence of participants in the ANOVA would not be achieved and degrees of freedom would have to be reduced. Most importantly, these inter-dependences were found whereas each participant of each pair could not see the stimulus the other subject of the pair was presented with and, thus, could not verify whether or not the statements were true.

Usual interpretations of these ERPs difference could be ruled out. First, because, in contrast with the second hypothesis, there was no effect of the conditions of the study phase on the scores of the memory test phase. The ERP differences found between the conditions of study phase could thus not be related to a Dm effect; that is, to larger P600s at fronto-central electrode sites for stimuli that benefit from a deeper encoding in episodic memory^{20,21}. Second, the ERP differences found were also unlikely to be related to differential allocations of attentional resources. Indeed, all stimuli had the same task relevance since they equally had to be memorized. Moreover, they could not capture attention differentially, since their use for each of the conditions of the study phase was counterbalanced across pairs of participants.

The statements seen by participants as to whether or not they would be presented with the same stimuli as the other participant of the pair could have theoretically modulated the allocation of attentional resources and thus P600 amplitudes. Nevertheless, these statements could not have had an effect depending on whether or not the

stimuli were actually consistent with the statement, since it was something participants had no knowledge of. Third, more preconscious processing does not seem to be useful to account for the greater P600s obtained in the inconsistent than in the consistent conditions. Indeed, why would more processing occur for inconsistent- than for consistent-conditions when all stimuli equally had to be memorized?

On the other hand, participants were side by side and could hear and see each other in their very peripheral visual field (i.e., 90 degrees). Thus, they could in principle influence each other (e.g., through breathing variations, subtle body movements, like postural reactions to aversive stimuli, facial mimicry, eye movements etc). It thus has to be discussed whether or not the present results could be in line with Dumas' *et al.* work²² on hyperscanning and inter-brain synchrony mediated through the mirror neuron system. Given that our participants did not have any task to perform, other than to look at the stimuli, part of their attention could have been allocated to what their partner was doing. Therefore, we have to ask whether the processing of the partner's movements could have been responsible for our results. At first, this does not seem impossible since, when participants were not seeing the same stimuli, they might not "be moved" in the same way and their systems might have detected that move difference. However, to account for the results obtained here, the effect of such a detection would also have to depend on the statement. When the subject was told (s)he will be presented with same stimuli, then, the move difference detected should be further processed since it is contradictory information. Nevertheless, ERP results are not in accordance with this interpretation. The unexpected effect found in the N400 time window show that inconsistency of the information with the belief was taken into account and had consequence on stimulus processing. This consequence started as early as the time of onset of the N400 whereas much longer time appears to be necessary for all the necessary steps, which include; the processing of the stimulus, the activation of an appropriate emotional response, the execution of this response, its processing from the very peripheral visual field of the other participant and the detection of its inconsistency with the expectancies of this participant. It thus appears very unlikely that the effect of consistency found here could be due to partner's moves.

Thus, in accordance with the first hypothesis, the larger P600s in statement inconsistent- than in statement consistent-conditions can be used to support the existence of spontaneous brain-to-brain communications (together with smaller N400s). These communications seem to permit our system to detect that others are not going through what we expected they would go through. The fact that, at the debriefing session, participants did not notice any deception shows that this detection remains unconscious. Thus, although P600s can index conscious process^{13,14,23,24}, the larger P600s obtained in inconsistent- than in consistent-conditions would not index the conscious detection of this kind of differences, in accordance with everyday life, where such things are inscrutable. But the fact that brain-to-brain communications can have such an impact on the P600s is consistent with the possibility of an additional content of consciousness that is neither verbalizable nor distinguishable from the qualia each participant would have had if (s)he were alone. In other words, the spontaneous brain-to-brain communications found could theoretically be responsible for mutual qualia enrichment as

hypothesized in the introduction. Qualia of others might contribute to our own by a merging process occurring without our knowledge. However, it is very important to point out that *nothing* in the present data *has* to be related to qualia. The P600 effects of consistency only support the existence of spontaneous and direct brain-to-brain influences that just *could* be related to consciousness.

Nevertheless, only qualia have been related to physical phenomena that propagate. Thus, although this relation is speculative, these are the only physical phenomena that can be discussed as those potentially underlying the direct brain-to-brain influences found. As mentioned, theories have been put forward that relate qualia to electro-magnetic fields, as reviewed by Jones¹⁰ and to the collapse of the so-called wave function studied in quantum mechanics, as proposed by Hameroff and Penrose¹¹. According to these ideas, qualia might then be responsible for the natural brain-to-brain communications found. The electromagnetic hypothesis can be based on the sensitivity to magnetic fields of at least two molecules: magnetite, whose presence has been demonstrated in the human brain²⁵⁻²⁷, and cryptochrome²⁸. Furthermore, it is consistent with the fact that mammal behaviors have been shown to depend on magnetic fields, such as that of the earth^{29,30}. However, two properties of magnetic fields are at odds with the idea that the magnetic fields generated by one participant could affect the brain activity of the other participant. First, the magnetic fields generated by the activity of the human brain (only 10 to 10³ femto Tesla) are much smaller than the magnetic noise of an urban environment (about 10⁸ femto Tesla). Second, magnetic fields decrease with the square of the distance. The heads of the two subjects of each pair were separated by about 40 cm, a distance much larger than the distance separating the brain from the devices used to capture the magnetic fields it generates in magneto-encephalography (MEG, i.e., less than one cm). Finally, our ERP recording room was not shielded like a MEG recording room. Urban magnetic noise was thus much more important than any field a human brain can generate. These factors make the electromagnetic field explanation appear less likely. In contrast, our experimental conditions and results seem to be more consistent with the *theories* of consciousness that see qualia as, at least partly, underlain by a modulation of the wave function, and that see direct brain-to-brain communications possible through quantum entanglement [e.g., 31]. Indeed, such modulations do not decrease with distance and could involve many atoms³². Nevertheless, it is pretty clear at this point that only speculations can be made as to the physical nature of the phenomena by which the activity of a brain could have an impact on the activity of another brain.

On the other hand, the finding of this impact raises the problem of irrelevant interferences. Indeed, the activity of many brains could then affect the activity of our own. It appears logical to think that filtering exists to prevent such perturbations. One possibility is that, the close relationship existing between the members of each pair in the present study is a prerequisite for the impact to occur, as it may depend on empathy and/or prior common memories. A further study should thus test whether the inconsistency effect reported here on ERPs could be found with pairs of participants who do not know each other before being tested together. On the other hand, filtering should also operate when the information is irrelevant, for instance when it is redundant with expectations and when the partner is not close by and/or when one is not concerned by what (s)he is going through.

There is a tradition of research studying the synchronization of EEGs and bold fMRI signals of two persons interacting, imitating each others' movements [e.g., 33] and of persons going through the same stimulation(s) [e.g., 34, for a review, see 35]. This tradition could be relevant since, here, we also recorded the EEG of two participants simultaneously. However, we used ERPs, not EEGs' synchrony or fMRI, and our participants were not interacting, imitating each other, or being presented with only the same stimulation. Each subject in a pair was going through the experiment on his/her own "despite" the fact that (s)he was sitting side by side with a friend/sibling/spouse. Sameness, and belief in that sameness, were manipulated, which both modulated the amplitude of a well-known ERP index of consciousness. To the best of our knowledge, there is thus yet no equivalent to the present study. The hypothesis of a direct sharing of qualia has never been tested. Future studies have to explore whether differential EEG synchrony can also occur within the present design and also test whether qualia sharing could account for part of the EEG synchrony observed in interacting participants. Indeed, the conscious intention to perform an action, when imitating, can be considered as a qualia and could, according to the present results, impact the functioning of the brain of the interacting person.

It has to be noted that, if further replicated, these findings could open several avenues of research. For instance, it might be interesting to explore whether young children's brains, or recovering brain damaged patients, learn to produce their qualia with the help of others. It could also be interesting to see if autistic children suffer from a disability of this learning mechanism or whether their tendency to limit contact with others is a strategy that protects them against a deficit of the filtering mechanism.

In any case, the results of the present study provide preliminary data that can be used to support the existence of direct and spontaneous brain-to-brain communications. Further studies are necessary to replicate these findings, to determine the physical bases of these communications, to see whether or not they also occur between persons who are not closely related to each other and to establish if these communications are associated to the mechanisms by which qualia pertaining to the same stimulus could be similar across individuals, a similarity that is assumed in almost every social interaction.

Data availability

F1000Research: Dataset 1. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the P600 time window, [10.5256/f1000research.5977.d100682](https://doi.org/10.5256/f1000research.5977.d100682)³⁶

F1000Research: Dataset 2. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the N400 time window, [10.5256/f1000research.5977.d100683](https://doi.org/10.5256/f1000research.5977.d100683)³⁷

F1000Research: Dataset 3. Mean voltages of the event-related brain potentials elicited by the IAPS stimuli in the P600 time window for BS and BD conditions, [10.5256/f1000research.5977.d100684](https://doi.org/10.5256/f1000research.5977.d100684)³⁸

Author contributions

J. Bruno Debruille wrote the research project that was accepted by the Research and Ethics Board of the Douglas Institute, designed the experiment, interpreted the data and wrote the introduction and the discussion of the manuscript. Sheila Bouten built the stimulus sequences, recruited the participants, tested them, analyzed the data, took part in their interpretation, wrote the method and the result section of the paper and proof read all the preliminary versions of the manuscript. For the second version, Hugo Pantecouteau computed new averages using EEGLab and ERPLab, measured these ERPs and analyzed the new measures to verify the absence errors in the first version.

Competing interests

No competing interests were disclosed.

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I have no further comments

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I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

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“Qualia” are always an interesting topic because it appears to bridge philosophy, psychology, physiology and our own experience in a way that very little can be argued beyond beliefs. Two questions are raised by this communication. The first one is whether humans share the same qualia and the second is whether an individual’s qualia can be influenced by the qualia of another individual.

The first question has been examined by many experiments in vision research. One way to answer this question is to find exceptions to the shared qualia. For vision, an obvious example is the variation of opsin genes in retinal cones (OPN1SW OPN1MW or OPN1LW). There is also the contested possibility (Jameson et al, 2014; 2016) that a small proportion of women have 4 opsin genes (tetrachromat) – an occurrence that is common in many animals (birds, frogs, insects Scholtyßek et al, 2017). Qualia are clearly affected by the different inputs from the retina containing variants of the opsin distribution in humans. Developmental color blindness is usually based on these variants.

There is also acquired color blindness of toxic origin in the retina (Choi, 2017) or from selective cortical lesions that induce achromatopsia within a visual field with preserved vision (Beauchamp et al. 2000). Self-reports in case study of acquired cortical achromatopsia suggest that all qualia modes (conscious

perception, imagery and dreams) are equally affected (Sacks, 1987). Finally, the most common manifestation of synesthesia involves color percept on black and white letters.

Color synesthesia either acquired or developmental is associated with unusual connectivity between various brain areas and the “V4” area in the visual cortex (Amsel, 2017). Developmental synesthesia has a genetic component that is being examined (Tilot et al., 2018).

These “abnormal” acquired variants and rare developmental variants are relatively clear demonstration that qualia, in this case color qualia, can differ among individuals. Many people with developmental color-word synesthesia are often unaware that their color qualia is different until they are older suggesting that many subtle variants are unknown because people are unaware that they are at variant with the general population. Several factors also appear to influence color perception and cognitive identification including aging, as well as language and culture

I now return to the majority of humans that have the expected cones and opsins as well as brain connectivity that apparently produce typical color perception and we assume typical qualia. Do these prerequisites of color perception sufficient to produce a common color qualia in the majority of humans. Although the source of variation is enigmatic, two people can have very different sensitivities to wavelength and label the same physical stimuli very differently (Webster, 2014). The most important source of variation comes from the differences in macular and lens pigment density (Webster & MacLeod, 1988). A common polymorphism in the OPN1LW gene produce a small but functional shift in the peak spectral sensitivity for long-wave light (Winderickx et al, 1992). Finally there is a large variation in the relative number of each of the three cones across people with normal vision (Hofer, Carroll, Neitz, Neitz, & Williams, 2005).

This lengthy introduction to this review suggest that humans, in general, do live in a delusional world where they think that all people experience the basic aspects of colour perception more or less exactly as they do. This delusion is mostly hidden behind our other delusion that even though colors are perceived the same, people can have preferred colors and can evaluate coloured garments as matching differently. However we know that social pressures can lead to temporary social consensus regarding the aesthetics of certain colours (e.g. the “avocado green” and “harvest gold” appliances of the 1970’s).

The present experiment examines the impact of the knowledge of another person perceptual judgement can influence or bias another person. In order to remove qualitative estimates, the experimenter chose to measure evoked potentials. Two participants were tested at the same time and presented simultaneously (but out of view of the other participant) two pictures that could be either the same or two different pictures. Before each trial, each participant was told whether the other participant was viewing a pair of pictures that were the same or different.

The question asked was whether knowledge of what the other participant was seeing (same/different) was sufficient to induce different evoked potentials patterns in the 4 conditions. The authors found that in the inconsistent conditions induced a slight variation in the P600 evoked potential in all electrode groups (e.g. the pictures presented were the same but the participant was told that the other person would see different pictures in their pair). The key event here is that the participants were misled about the pictures seen by the other participant – either by displaying a statement saying that the pictures would be different but were not OR that picture would be the same but were actually different. These two conditions were contrasted with two other conditions where the statements were congruent with the presentations. The authors argue that because the participants had no way of overtly knowing whether the statements were true or not, that information had to be exchanged directly from brain to brain.

Although I understand the enthusiasm of the authors regarding this possibility, one has to realize that we do exchange information between brains using numerous sensory/perceptual channels – some of which are obvious (like language) and some less obvious. In the experiments, the authors did take pains to verify some of the obvious channels that would not rely on “brain-to-brain” information exchange. However because this type of exchange is considered very unlikely by most, the authors should be held to a much higher standard to eliminate all other possibilities – some of which could be very subtle.

Although I have not experienced the testing situation, I can only offer some speculations. For example, it is likely that the luminance of the pictures presented on the two halves of the screen shared by participants resulted in some reflected glare that could be somehow be detected – possibly without consciousness. Also, the screen could present subtle differences when presenting two identical pictures compared to different pictures on the two half-screen portions. The point here is that exceptional claims have to be tested in several experimental contexts that are highly controlled before one allows the support of unconventional hypotheses. This is a typical human and scientific bias but not an unreasonable one. Sometimes this higher standard of proof slows down science progress but sometimes it uncovers uncontrolled variables that refute the unconventional hypothesis. An example of an additional test of the brain-to-brain hypothesis would be to use auditory information presented with soundproof earphones.

As it stands, we have interesting results and the authors propose an unconventional hypothesis based on the absence, for them, of other alternative hypotheses. As the saying goes, additional data are needed.

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Is the work clearly and accurately presented and does it cite the current literature?

Yes

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 30 May 2018

J. Bruno Debrulle, McGill University, Canada

Thank you for this very interesting review. We learned quite a few things about the variations of color perceptions and do accept that some individuals, due to their biology, have color qualia that differ from those of others. We also agree with the conclusion that:

"humans, in general, do live in a delusional world where they think that *all* people experience the basic aspects of color perception more or less *exactly* as they do." because of the words we italicized in that quote. In effect, these words allow us to maintain our claim that, *globally*, a vast number of people experience color qualia in a *similar* way.

It is then logical to ask how that can be whereas this similarity does not appear to be based on neural networks' similarity. In effect, after a stroke damaging the visual cortex, some patients recover the ability to generate old qualia in new areas and thus in other neural networks. Or, in blind people, it seems that the visual cortex can generate sound qualia.

One simple and straightforward way that a vast number of people can experience similar qualia is by influencing each other. This way, the brains of children, for instance, which are both macroscopically and microscopically different from those of adults, can learn to generate qualia similar to those of their parents. We thus maintain that there is a logic in looking for an impact of qualia on the brain of others.

We acknowledge that hypothesizing such an impact is assuming that qualia have a physical nature (which then remain to be discovered). But, would it be scientific to talk about something without assuming such a nature? Wouldn't that create the mind-body problem by saying that brains, which are material, could create something (i.e., qualia) that have no physical nature?

For many, qualia *emerge* from particular patterns of neural activation and those patterns are all the physics involved. However, this emergence idea contrasts with the 3 D movie (Chalmers), which is made by the brain integrating the various qualia it created into a perceived world in which we feel. How could one say that this movie *is* such patterns? It appears very counterintuitive. To illustrate this counter intuitiveness, one could transpose the emergence idea to computers. One would then be saying that the activity of the graphic processing unit, for instance, would *be* the visual display, which does not make sense. Moreover, restricting each quale to the particular pattern of neural activity, from which it would emerge, leaves us with problem created by the possible lack of neural networks' similarities mentioned above.

So, it makes sense to say that the qualia generated by the brain a) have their own physics and b) can be generated by different neural networks provided that these networks learn to develop the appropriate activity.

Saying that qualia are physical makes it easier to understand why our brains are sensitive to them, as since shown by our reactions to the perceived world.

And, if brains are sensitive to the qualia they created, there is an easy way to understand how a vast number of people can learn to produce similar qualia: again, by a sensitivity of their brains to the qualia of others.

We want to emphasize that logic because, to the best of our knowledge, it is the first time that it is used.

Response to comment two:

“ In the experiments, the authors did take pains to verify some of the obvious channels that would not rely on “brain-to-brain” information exchange. However because this type of exchange is considered very unlikely by most, the authors should be held to a much higher standard to eliminate all other possibilities – some of which could be very subtle. »

« Although I have not experienced the testing situation, I can only offer some speculations. For example, it is likely that the luminance of the pictures presented on the two halves of the screen shared by participants resulted in some reflected glare that could be somehow be detected – possibly without consciousness. Also, the screen could present subtle differences when presenting two identical pictures compared to different pictures on the two half-screen portions. »

We agree. This glare is indeed something we should have thought about.
We thus went back in the testing room and run the stimulus sequence.

Just as when participants were there during the experiment, we switched on the dim lights (=two alarm bulbs powered by a battery) that are on the ceiling of the participants' room.

During the display of the stimuli, the walls of that room appear to reflect only the light of the dim lights, not the light from the images appearing on the computer screen, which is too weak. We also look at the screen itself to see whether the white that was surrounding IAPS images depends a bit on the image presented on the other half of the screen. None of the members of the lab present at that time were able to detect changes in that white along with the display of the images, leave alone using that to say whether the two images were the same or different. The white screen surrounding the image just does not appear to change when images occur.

On the other hand, in a follow-up study, we used the faces of the MED-bank, which are photographs of people who were shot on the same background, using the same lighting, lens and film. These pictures thus induce similar glares. Nevertheless, we still found an effect of qualia on ERPs of close others with those other stimuli.

On the other hand, in a follow-up paper that has just been submitted at BioRxiv, we separated the two partners of each pair with a black curtain, which went much higher than their heads. This was done so that they could not see each other in the very periphery of their visual field. Nevertheless, the curtain also prevented them from seeing the wall that was next to the half of the screen of the partner, and thus from detecting a glare of the image presented to this partner. In this setting, we also found an effect of qualia on the ERPs of 32 close-others.

In this follow-up paper, we also had a group of 34 strangers. These latter participants, who never saw each other before the experiment, did not have significant effect of qualia of others on their ERPs, despite the fact that they were not separated by a curtain.

We would like also to point again the particular nature of the ERP effects obtained on the N400 and on the late posterior-central positivity (i.e., the LPP, also named the late positive complex or the P600). The fact that the N400 was significantly smaller for stimuli which were *inconsistent* than for those which were consistent and that LPPs were greater is not something we could have had by *presenting* incompatible information to participants. When such information occurs and is consciously detected by participants in usual designs, N400s are well-known to be larger and P600s smaller.

To conclude, we would say that there is thus more than one reason for which it is very difficult to account for the present ERP effects using “classical” human to human communications. Nevertheless, we are of course running other studies to replicate and extend.

Competing Interests: We declare having no competing interest

Referee Report 29 October 2015

doi:10.5256/f1000research.7505.r10137



André Achim

Department of Psychology, Université du Québec à Montréal, Montréal, QC, Canada

The new title usefully resets the scope of the present work. Although the origin of the project remains the hunt for an electrophysiological correlate of qualia and the discussion retains such aspect, the present version of the research report settles on a more modest, but still quite bold, interpretation of the ERP

results. Hopefully, the readers of the report will acknowledge the data and their statistical analyses, and will take the authors' speculations about qualia and about direct brain-to-brain communication as possible although not necessary explanations. Since direct brain-to-brain communication is quite close to parapsychology, and especially to extra-sensory perception (ESP), the topic calls for an extra amount of skepticism.

It is unfortunate that the authors chose to move the data analysis window from 600-900 ms in the first version to 650-950 ms post stimulus onset in the present version, although not consistently so since the effect of belief still uses the 600-900 ms range. The change in analysis interval seems related to explorations aimed at improving the statistical significance of the data, which would be a questionable scientific practice. I will therefore assume that the *a priori* specification of the interval of interest, presumably not guided by inspection of the data, is the 600-900 ms range.

In the present version of the report, the authors substituted two separate ANOVAs to their original Sameness x Belief 2X2 design. In the present version, the analysis for the Belief effect, also referred to as the social cognition effect, remains the same as in the 2x2 design, and the Concordance effect, except for the 50 ms shift in the data interval, is the same as the interaction in the previous 2x2 design. Had the analysis remained 2x2 but with Concordance as a main effect, then the Concordance x Belief interaction would have been the Sameness main effect of the earlier 2x2 analysis. Sticking to the *a priori* selected 600-900 ms interval allows discussing the interaction that is missing in the present revision. The authors' explanation that averaging over two conditions for each of the separate ANOVAs (e.g. over the two Belief conditions for each Concordance condition for the ANOVA on the Concordance effect) should improve the signal-to-noise ratio is an oversight (except for the graphs) for statistical analysis since the 2x2 ANOVA already achieved that effect (averaging the two amplitude values of each subject is equivalent to computing the amplitude of the common averaged waveform, with very mild modulation by unequal number of stimuli in the two conditions pooled together).

The reasoning leading from considerations of qualia to the analysis of ERP amplitude in the time interval of the P600 appears extremely opaque. If, for instance, the specific subjective experience of blue in one person was to be shared through the modulation of EEG signals, this modulation would need to differ from that of the subjective experience of green. Since each qualia would need its own signature, measuring the P600 amplitude can hardly reflect the information. With the shift in emphasis from qualia to direct brain-to-brain communication, similar problems remain undiscussed: What would be the contents of that direct brain-to-brain communication? Is the effect rich enough to convey a reasonably large variety of contents?

The possibility that the ERP effects index direct brain-to-brain communication is definitely worth reporting. Before accepting the conclusion as quite likely, however, the readers should await elimination of alternate, more mundane, explanations. In the present revision, the authors acknowledge the possibility that subtle cues would be transmitted from one participant to the other in reaction to some emotional stimuli, but argue that the time required for one participant's brain to process the information and emit a bodily response plus the time required by the partner to perceive and process that response is inconsistent with the time of onset of the observed ERP difference. There are other possibilities however that will need to be ruled out experimentally for the direct brain-to-brain interpretation to hold. The subconscious perception, in the DBs condition, that the partner reacts emotionally (perhaps expressed by a contraction of the hand) when the currently seen picture does not justify it could alert the participant for extra processing of the sequence of stimuli. This, however, does not have to be a strict stimulus by stimulus effect and could well affect the processing of upcoming stimuli. For the SBd condition, the other member of the non-concordant condition, this alternate explanation is, however, not so obvious to

formulate.

The lack of condition differences among SBs, SBd and DBs, reported in my comments on the previous version does not support the alternate interpretation formulated here, although only SBs is expected to differ from the other two in the context of a concordance effect. To further question the merit of the alternate hypothesis, there is interest in the interaction between the two dimensions analyzed in the present version. This is the Sameness effect in the earlier report, which was significant or marginally so in the parasagittal ($p=.07$) and lateral ($p=.04$) electrode sets. It is thus conceivable that the Concordance effect and its interaction with Belief would indicate that the Concordance effect is more important (perhaps only present) for one of the four test conditions. It becomes relevant to assess whether the interaction suggests that the concordance effect would indeed be stronger for DBs compared to SBs than for DBd compared to SDd. If the effect was essentially that of DBs differing from the remaining three conditions, a Belief effect should also be expected. No Belief effect was reported in Table 2 of the previous version, but Table 3 documents significant differences of DBd with both of DBs (a Belief effect) and SBd (a Sameness effect). How would the concordance effect be re-interpreted if it was present only for the believe-different conditions (seen in Table 3 of previous version) but not for the believe-same conditions (i.e. SBs vs DBs)?

Other forms of alternate interpretations remain possible. For instance, the SBd condition could induce the subconscious perception that the partner is moved similar to oneself, leading to the suspicion that the stimuli, although different, would be matched for emotional contents. This could also add the extra processing of the remaining stimuli in the block. The statement in the abstract that the participants had no way to detect inconsistency is premature since it relies essentially on each participant not seeing the stimulus presented to the partner. I agree however that there was no obvious way by which the information about inconsistency (or perhaps about consistency) could be conveyed by visual, auditory or tactile cues; direct brain-to-brain communication remains a possibility, although one requiring the exclusion of simpler alternatives.

Later experimentations should therefore concentrate on eliminating the possibility that response cues (of perceptual-emotional origin) modulate the processing of later stimuli, by adding the dimension that not only the stimuli but also the partner's reactions are monitored in some of the conditions. The direct brain-to-brain hypothesis does not require that the partners should see or could hear noises from each other, although it may be speculated that being aware of the presence of the other person would be required. Fitting the participants with ear plugs and with eye screens preventing lateral visual perception should retain the impression of the presence of the other while blocking most signs of emotional reaction (floor vibration would not be excluded).

Given the structure of publication in F1000Research, it would not be required that the authors amend the current version for the readers to become aware that simpler alternate explanations must be excluded before accepting the ESP interpretation. This being said, a number of more minor points are worth addressing.

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Page 4, column 2, "The 32 subjects of the 16 pairs underwent ..." I find the simplification hardly acceptable, since the earlier version of the report and the accompanying data file provide evidence that there were only 14 intact pairs (13 d.f. in the correlations tests reported in my earlier comment). It would have been far better to describe how many dyads were tested and to explain on what grounds subjects were excluded.

Opinion:

In the abstract, "no way to see the stimulus their partner was presented with, and thus no way to detect inconsistency" is currently an over optimistic statement.

In the "Amendments from version 1" box, the authors mention averaging the consistent and the inconsistent conditions over the two believe conditions, partly to increase signal-to-noise. This is not at all an argument for not analysing belief and consistency effects in the same ANOVA, since the amplitude of an average is the same as the average of the amplitudes when there is an equal number of individual sweeps in the two conditions (and very nearly so for comparatively large numbers of sweeps).

Clerical:

In the abstract the word 'inconsistent' is split between two lines without hyphenation.

Page 4, column 2, line 8: "if, and only if, that there is no way"

In the Data Acquisition paragraph, only 26 of the 28 channels are listed, FP1 and FP2 present in the figures are missing here.

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Page 14, first paragraph, "of" is missing in "to verify the absence errors".

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 05 Sep 2016

J. Bruno Debruille, McGill University, Canada

The new title usefully resets the scope of the present work. Although the origin of the project remains the hunt for an electrophysiological correlate of qualia and the discussion retains such aspect, the present version of the research report settles on a more modest, but still quite bold, interpretation of the ERP results. Hopefully, the readers of the report will acknowledge the data and their statistical analyses, and will take the authors' speculations about qualia and about direct brain-to-brain communication as possible although not necessary explanations. Since direct brain-to-brain communication is quite close to parapsychology, and especially to extra-sensory perception (ESP), the topic calls for an extra amount of skepticism.

We agree with these comments for the most part. However, parapsychology and telepathy

do not focus on the means by which our percepts of a real stimulus can be similar to the percepts generated by that stimulus in other individuals despite brain differences. Moreover, the word parapsychology suggests an explicit quest for facts and data that would be somehow apart from psychology. On the contrary, our goal is to account for a usual psychology fact.

It is unfortunate that the authors chose to move the data analysis window from 600-900 ms in the first version to 650-950 ms post stimulus onset in the present version, although not consistently so since the effect of belief still uses the 600-900 ms range. The change in analysis interval seems related to explorations aimed at improving the statistical significance of the data, which would be a questionable scientific practice. I will therefore assume that the *a priori* specification of the interval of interest, presumably not guided by inspection of the data, is the 600-900 ms range.

The time window of measure has not been moved, neither for consistency nor for belief! Exploring the latency of early ERPs, we detected they appeared to peak too early. We run tests. They proved that the photo-transistor placed on the screen to detect the real time of onset of the stimuli was providing the EEG computer with a trigger that was systematically delayed by 50 ms. In the second version of the paper, we decided to take that into account. So, we were already measuring the mean voltage between 650 to 950 ms in the first version. In the second version, we thus mentioned this real time window of measure and corrected Figures 2 and 3, which thus now include the -.16 s. in the x axis.

In the present version of the report, the authors substituted two separate ANOVAs to their original Sameness x Belief 2X2 design. In the present version, the analysis for the Belief effect, also referred to as the social cognition effect, remains the same as in the 2x2 design, and the Concordance effect, except for the 50 ms shift in the data interval, is the same as the interaction in the previous 2x2 design. Had the analysis remained 2x2 but with Concordance as a main effect, then the Concordance x Belief interaction would have been the Sameness main effect of the earlier 2x2 analysis. Sticking to the *a priori* selected 600-900 ms interval allows discussing the interaction that is missing in the present revision. The authors' explanation that averaging over two conditions for each of the separate ANOVAs (e.g. over the two Belief conditions for each Concordance condition for the ANOVA on the Concordance effect) should improve the signal-to-noise ratio is an oversight (except for the graphs) for statistical analysis since the 2x2 ANOVA already achieved that effect (averaging the two amplitude values of each subject is equivalent to computing the amplitude of the common averaged waveform, with very mild modulation by unequal number of stimuli in the two conditions pooled together).

Yes, the interaction between belief and reality (=sameness) is equivalent to the concordance effect. But we think it is easier to understand this concordance than to speak about an interaction between these two factors. Moreover, taking advantage of the format of this journal, readers will have both approach by looking at the first and second version. For the 600-900 to 650-950, please see our response to the previous comment.

The reasoning leading from considerations of qualia to the analysis of ERP amplitude in the time interval of the P600 appears extremely opaque. If, for instance, the specific subjective experience

of blue in one person was to be shared through the modulation of EEG signals, this modulation would need to differ from that of the subjective experience of green. Since each qualia would need its own signature, measuring the P600 amplitude can hardly reflect the information. With the shift in emphasis from qualia to direct brain-to-brain communication, similar problems remain undiscussed: What would be the contents of that direct brain-to-brain communication? Is the effect rich enough to convey a reasonably large variety of contents?

Thoughtful comment, and of critical importance. All we know is that (1) there is a relation between the amplitude of the late posterior positivity (LPP or P600) and putting new information into the “working memory part of consciousness” (see S. Luck and S. Dehaene work on attentional blink for instance). On the other hand, (2) the results of the present paper suggest that there could be direct brain to brain communications. Finally, (3) we know that such communications would be very useful to understand how qualia can be similar across individuals. The problem is how to link those these three elements. Many possibilities can be discussed. The most parsimonious hypothesis is that the brain activities responsible for the consciousness of a qualia are those that are responsible for a signal to which the brain of the partner is sensitive to. However, there is no way to know whether the emission of this signal and/ or its “reception” is indexed by the LPP. The modulation of this ERP could be an (a posteriori) consequence of the processing of that signal, which could be emitted during preconscious processing, rather than during the consciousness of the qualia....

This is now included in the discussion section of the version 3 of the paper, during the paragraph starting with “However...” p 23.

The possibility that the ERP effects index direct brain-to-brain communication is definitely worth reporting. Before accepting the conclusion as quite likely, however, the readers should await elimination of alternate, more mundane, explanations. In the present revision, the authors acknowledge the possibility that subtle cues would be transmitted from one participant to the other in reaction to some emotional stimuli, but argue that the time required for one participant's brain to process the information and emit a bodily response plus the time required by the partner to perceive and process that response is inconsistent with the time of onset of the observed ERP difference. There are other possibilities however that will need to be ruled out experimentally for the direct brain-to-brain interpretation to hold. The subconscious perception, in the DBs condition, that the partner reacts emotionally (perhaps expressed by a contraction of the hand) when the currently seen picture does not justify it could alert the participant for extra processing of the sequence of stimuli. This, however, does not have to be a strict stimulus by stimulus effect and could well affect the processing of upcoming stimuli. For the SBd condition, the other member of the non-concordant condition, this alternate explanation is, however, not so obvious to formulate.

We agree that there was an unlikely possibility that a subconscious perception of such an unjustified alert could have impacted the processing of upcoming stimuli. This was thus added to the paper, end of p22, just before mentioning: the impact of subliminal information on the processing of upcoming stimuli is usually very short. For instance, the priming induced by the prior presentation of a subliminal word that is semantically associated to an upcoming target words, lasts at most a few hundred milliseconds. Negative priming lasts longer but at most 8 seconds, which would only impact the two trials in the current experiment, and it depends on an effortful ignorance of distractors

that may have been consciously perceived at first.

The lack of condition differences among SBs, SBd and DBs, reported in my comments on the previous version does not support the alternate interpretation formulated here, although only SBs is expected to differ from the other two in the context of a concordance effect. To further question the merit of the alternate hypothesis, there is interest in the interaction between the two dimensions analyzed in the present version. This is the Sameness effect in the earlier report, which was significant or marginally so in the parasagittal ($p=.07$) and lateral ($p=.04$) electrode sets. It is thus conceivable that the Concordance effect and its interaction with Belief would indicate that the Concordance effect is more important (perhaps only present) for one of the four test conditions. It becomes relevant to assess whether the interaction suggests that the concordance effect would indeed be stronger for DBs compared to SBs than for DBd compared to SDd. If the effect was essentially that of DBs differing from the remaining three conditions, a Belief effect should also be expected. No Belief effect was reported in Table 2 of the previous version, but Table 3 documents significant differences of DBd with both of DBs (a Belief effect) and SBd (a Sameness effect). How would the concordance effect be re-interpreted if it was present only for the believe-different conditions (seen in Table 3 of previous version) but not for the believe-same conditions (i.e. SBs vs DBs)?

This is an interesting question. In the first version, we discussed some possibilities. It may be the case that, in young adults, and thus in individuals who have already learned to produce most qualia, the belief that their partner is seeing the same stimulus prevents their system from using the information, taking for granted that it already has everything. If this hypothesis were correct, there should then be a difference between the two believe-same conditions only in the case of children. Then, at some age, brains would be mainly "interested" in "trying to guess" what close ones go through in the case it differs from what we go through.

Other forms of alternate interpretations remain possible. For instance, the SBd condition could induce the subconscious perception that the partner is moved similar to oneself, leading to the suspicion that the stimuli, although different, would be matched for emotional contents. This could also add the extra processing of the remaining stimuli in the block. The statement in the abstract that the participants had no way to detect inconsistency is premature since it relies essentially on each participant not seeing the stimulus presented to the partner. I agree however that there was no obvious way by which the information about inconsistency (or perhaps about consistency) could be conveyed by visual, auditory or tactile cues; direct brain-to-brain communication remains a possibility, although one requiring the exclusion of simpler alternatives.

Yes. We agree in principle. Although we think it is very unlikely that a "subconscious perception that the partner is moved similar to oneself, leads to the 'unconscious' (our addition) suspicion that the stimuli, although different, is matched for emotional contents." See also above, in response to a prior comment, the duration of the effects of subliminal information.

Later experimentations should therefore concentrate on eliminating the possibility that response cues (of perceptual-emotional origin) modulate the processing of later stimuli, by adding the

dimension that not only the stimuli but also the partner's reactions are monitored in some of the conditions. The direct brain-to-brain hypothesis does not require that the partners should see or could hear noises from each other, although it may be speculated that being aware of the presence of the other person would be required. Fitting the participants with ear plugs and with eye screens preventing lateral visual perception should retain the impression of the presence of the other while blocking most signs of emotional reaction (floor vibration would not be excluded).

Good ideas. Thank you. We have run a study with a black curtain separating the partners. The consistency effects remained (submitted). For next studies, we are also considering making a video of the participants during the experiment to check their movements and the noise they could make.

Given the structure of publication in F1000Research, it would not be required that the authors amend the current version for the readers to become aware that simpler alternate explanations must be excluded before accepting the ESP interpretation. This being said, a number of more minor points are worth addressing.

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We agree that F7 ERPs for participants who were on the right of their partners look smaller than ERPs of participants who were on the left of their partner. This could indicate differential eye movements. However, we have been deceived many times by comparing ERPs across subjects with less than 20 participants per group, and here, we only have 16 for each of these subgroups. Moreover, notable eye movements trigger huge effects on waves. Thus, even if the F7/ F8 differences signaled were reliable, it would indicate, at most, subtle eye movements, thus totally out of proportion to what would be necessary to focus on the other participant and his/her reactions. And, as mentioned, even looking side ways could not help them to see the stimulus presented to their partners. For this, they would also have had to move their body or to move the cardboard.

Page 4, column 2, "The 32 subjects of the 16 pairs underwent ..." I find the simplification hardly acceptable, since the earlier version of the report and the accompanying data file provide evidence that there were only 14 intact pairs (13 d.f. in the correlations tests reported in my earlier comment). It would have been far better to describe how many dyads were tested and to explain on what grounds subjects were excluded.

Four subjects of the initial 16 pairs were excluded because of problematic ERPs. For them, too many trials had to be rejected and hardly any ERPs could be obtained, a frequent problem when having no reaction time task. These 4 subjects did not belong to the same pairs. There were only 12 intact pairs. Two more pairs were thus recruited to

reach 32 participants, which is why there was only 14 intact pairs at the end.

The Participants paragraph of the Method section was corrected accordingly (p 8).

Opinion:

In the abstract, "no way to see the stimulus their partner was presented with, and thus no way to detect inconsistency" is currently an over optimistic statement.

Agreed. we added « a priori » (and thus: “a priori no way to detect inconsistency”).

In the "Amendments from version 1" box, the authors mention averaging the consistent and the inconsistent conditions over the two believe conditions, partly to increase signal-to-noise. This is not at all an argument for not analysing belief and consistency effects in the same ANOVA, since the amplitude of an average is the same as the average of the amplitudes when there is an equal number of individual sweeps in the two conditions (and very nearly so for comparatively large numbers of sweeps).

We agree, but we take advantage of the format of this journal, which makes the previous versions available to the readers. They can see the results of both approaches.

Clerical:

In the abstract the word 'inconsistent' is split between two lines without hyphenation.

Corrected

Page 4, column 2, line 8: "if, and only if, that there is no way"

Corrected

In the Data Acquisition paragraph, only 26 of the 28 channels are listed, FP1 and FP2 present in the figures are missing here.

Corrected

Page 11, 2nd paragraph, "if" is missing in "Indeed, this were the case, one would have ...".

Corrected

Page 14, first paragraph, "of" is missing in "to verify the absence errors".

Corrected

Many thanks.

Competing Interests: We declare we have no competing interest.

Version 1

Referee Report 07 January 2015

doi:[10.5256/f1000research.6394.r7149](https://doi.org/10.5256/f1000research.6394.r7149)

**André Achim**

Department of Psychology, Université du Québec à Montréal, Montréal, QC, Canada

The scientific study of consciousness is extremely difficult. Any serious attempt should therefore be regarded with a positively open mind. The intellectually challenging results of the present experiment, however, are unlikely to pertain to understanding the nature of qualia in the human brain. They rather seem to hint at a social cognition effect.

Design

The data consist in the average amplitude from 600 to 900 ms post stimulus onset of event related potentials (ERP) to complex stimuli selected as “most striking pictures” from the International Affective Picture System (IAPS). EEG recordings were obtained from dyads of socially related participants, simultaneously presented on separate halves of the same screen with a picture that could not be seen by the other participant, even though they were seated side by side and could see each other in the periphery of their visual field. Each participant had to observe the pictures in order to recognise them in a later memory test.

Four different ERP conditions are compared, each consisting of the average of 70 stimuli (minus occasional artefacts at some channels) obtained from the same block. Two of the blocks were introduced to the two participants to consist of identical stimuli simultaneously presented to each of them, and the remaining two blocks were announced to consist of different sets of pictures. In each pair of conditions, this initial announcement was faithful once and contrary to the actual situation the other time. This allowed analyzing the situation in a 2 x 2 design of Sameness (Identical versus different pairs actually presented) by Belief (believing that the partner was presented with same versus different stimuli).

The recordings, in each participant, were from 28 channels, referred to right ear lobe, not including any EOG dedicated channels. Each picture was presented for 1.0 s with a mean expected inter stimulus interval just below 1.15 s. Therefore, each of the four stimulus block lasted only about 2.5 minutes. The following simultaneous testing phase of the two participants required 28 minutes (280 targets + 280 new items each presented for 3.0 s).

Although the rationale for the study considers qualia and the possibility of common brain signatures, the averaging over different stimuli in the same condition restricts considerably the relevance of the data to the original question of the nature of the qualia and of their physical support in the brain. The authors actually need to extend the concept of qualia to include the knowledge of whether the other person in the dyad is supposed to receive identical or different stimuli, which is very unlikely the dominant subjective experience (qualia) produced by any stimulus. The data are therefore much more likely to pertain to social

cognition than to the intended exploration of a physiological substrate for the qualia. Actually, for features of visual perception that do not play a role in the task (for instance by being rare versus frequent events or relevant versus irrelevant), the ERP differences are likely to be idiosyncratic, requiring special statistical technique to detect differences that take different forms in different brains (e.g. Buchsbaum and Fedio, 1969, 1970, for the ERP difference between geometrical patterns and three letter words made of the same number of dots).

ERP results.

Visual inspection of the averages shows that the ERP were negative, relative to the 200 ms baseline, for the full duration of the stimuli in all four conditions for all 12 channels anterior to Cz, and were entirely positive in 6 of the seven posterior channels, at the level of, or posterior to Pz, excluding Pz itself which is mostly negative up to about 400 ms and positive thereafter in all four conditions. Despite the large anterior-posterior inversion in overall ERP polarity, the amplitude differences between conditions remain constant in polarity across all channels.

The differences in condition are most marked between the two Believe Different conditions, with the Actually Same condition (SBd) being positive relative to the Actually Different condition (DBd). In the right hemisphere and posteriorly in the left hemisphere, the two Believe Same conditions (Actually Same and Actually Different, respectively SBs and DBs) were of intermediate amplitudes. In the frontal half of the left hemisphere, however, the ERP to the two Believe Same conditions overlap substantially with those of SBd, all three being less negative than DBd.

The lack of inversion of the condition differences suggests that the underlying dominant effect is unlikely a simple modulation of the dominant sources of these ERP. The left frontal distinction from the remaining ordering of conditions could indicate the presence of at least two sources modulated by the experimental conditions.

Although the data were analyzed with Belief and Sameness as factors, according to the experimental plan, it is relevant to decide whether the conditions SBs, SBd and DBs differ among themselves. Since the data are available, these could be tested. The following table gives the p value of all effects involving the three level Condition factor (DBd being excluded).

effect	Electrode group		
	Sagittal	Para sagittal	Lateral
Cond	.774	.699	.863
Cond x Hem		.353	.228
Cond x Elect	.208	.128	.489
Cond x Hem x Elect		.066	.131

Thus, even without correcting for these 10 tests involving Condition, there is no indication of any difference in this group of three conditions. Since there was no condition in which the participants were alone, it cannot be decided empirically whether the effect of watching stimuli in dyads affects essentially the DBd condition or the remaining three conditions.

The “operational hypothesis” that DBd would have a minimal impact on the ERPs implies that the topography in that condition is essentially that of the background activity. Since the background activity inverts polarity from front to back, this should also occur in the DBd condition. Since it does not, it becomes difficult to consider *de facto* DBd as the baseline no-effect condition. It could well be that DBd is the only condition that expresses the social cognition effect apparently present in the data.

Although *ad hoc*, the following explanation may be proposed for the present data in terms of social cognition. In the DBd condition, each partner might be interested in whether the other person is presented with a similar amount of emotion. This would also be so at the beginning of the SBd condition, but the impression would rapidly build that the stimuli, although believed different, would be matched for emotion and therefore this interest in the amount of emotion felt by the other person could fade. This would account for the SDD-DBd difference being the most reliably detected. For the two Believe Same conditions, each partner would not doubt that the other person receives the same amount of emotion, resulting in no difference between these conditions.

Correlations

The result section also includes correlations calculated for P600 amplitude differences between conditions. These are reported, in Table 4, only for “the conditions that were the most different from each other, namely, SBd-DBd and DBs-SBs”. This justification seems incorrect, given the above table showing no detected difference between SBd, DBs and SBs, and since additional tests of the latter pair does not show any difference at any channel (all $p \geq .073$). Reproducing the scatter plots of Figure 7 confirms that only 14 intact dyads were actually retained (an odd numbered participant followed by the next even number in the data base provided; the rationale for rejecting some participants should have been expressed). The situation, however calls for using the intra class correlation coefficient (ICC) in which no distinction is made as to which member should be A and which should be B, and for which only the common sample mean and common sample variance are used, resulting in one extra degree of freedom for the test, since only one mean is fitted to the data. When ICC are calculated, the following can be obtained (the sign after the channel name duplicates that of the correlation).

ICC in **SBd-DBd**: 4 channels with $p < .05$

9 $r = -0.5674$ $t(13) = -2.4843$ $p = 0.0274^*$ F8-

17 $r = -0.5438$ $t(13) = -2.3363$ $p = 0.0361^*$ Fz-

20 $r = -0.6196$ $t(13) = -2.8462$ $p = 0.0138^*$ P3-

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ICC in **DBs-DBd**: no channel with $p < .05$

ICC in **SBs-DBd**: no channel with $p < .05$

ICC in **SBd-SBs**: 1 channel with $p < .05$

21 $r = 0.6947$ $t(13) = 3.4823$ $p = 0.0040^{**}$ P4+

ICC in **SBs-DBs**: 3 channels with $p < .05$

18 $r = 0.5142$ $t(13) = 2.1617$ $p = 0.0499^*$ O1+

19 $r = 0.5305$ $t(13) = 2.2562$ $p = 0.0419^*$ O2+

21 $r = 0.6208$ $t(13) = 2.8551$ $p = 0.0135^*$ P4+

The other condition differences were not tested. Note that 8/140 (perhaps not independent) correlations tested have $p < .05$, while 7/140 is expected for independent statistical tests when H_0 is true. The critical value of p , with a Bonferroni correction (for 140 independent tests) would be .0018, not reached by any of the 140 tests.

Besides the possibility of there being no true correlation between the dyad members, the negative correlations between the dyad members, observed for the SBd-DBd difference, are counterintuitive. One could call upon disentanglement in which collapsing of the wave function for a particle causes the collapse of the complementary state, even at great distances. But here we have negative correlations on average amplitude differences. The quantum physics speculation not only would dispose of the phenomenon, assuming it is not a statistical accident, as being apparently explained, but this would

require further *ad hoc* speculations to explain that the wave function would systematically collapse in the same way in the same person in the given test situation.

If there is a true phenomenon to understand, we should start by questioning whether the negative correlations are mostly associated with SBd or with DBd. Note that since the same variable is used for both members of the dyads, changing its sign would not alter the direction of the correlation. It is unlikely that DBd is the source of the negative correlations since no significant ($p < .05$) correlation is seen in any other difference involving DBd. But the source of the negative correlation is not likely to be SBd either since the other tested difference involving SBd does not replicate the negative correlations. While the negative correlations for SBd-DBd were significant ($p < .02$) at P3 and Pz, it is a positive correlation that is significant ($p < .01$) at P4 for SBd-SBs. Since P4 also gives a significant ($p < .02$) positive correlation for SBs-DBs, the positive correlation for SBd-SBs is more likely attributable to SBs than to SBd (which was involved in the negative correlation).

Setting aside the problem of ascribing the negative correlation to one of the involved experimental conditions, some important insight about social cognition could come from trying to identify the characteristics which defines which member of a dyad would produce a large or positive difference between conditions and which one would produce small or negative differences. Could this, for instance, characterize an implicit cognitive domination-submission attitude? But whether any of these correlations reflects a true correlation remains to be established first. The above discussion casts serious doubts on this.

Technical details

In reporting the behavioral data in Table 5, the misses do not need to be reported, as they should be 70 minus the number of hits (not exactly so here probably because of rounding errors), but the false alarm rate for the 280 new pictures should be added to allow estimating the amount of guessing.

In Figure 2, it is not clear to what the 20 cm distance applies. It would be relevant, however to know how far apart from each other were the participants and at what distance from the screen were their eyes, so we can appreciate how much they could see of each other. Instead of the first and last half of participants, Figures 5 and 6 could provide the means from the participants on the left and those on the right (even though they are not the same in number), so that any tendency to gaze at the other person at some systematic time after stimulus delivery would be reflected by opposite shifts at F7 and F8. From the data available, there is no systematic group difference if F8-F7 in any or the four conditions, but that tells nothing of the 0-600 ms interval.

If systematic correlations existed between dyad members, the independence of participants in the ANOVA would not be achieved, so that the degrees of freedom would actually be inflated. This possible bias could be acknowledged, even though the presence of correlations is not very convincing.

On page 6: the statement “electrodes for which amplitude exceeded +/- 100 mV were discarded” would need clarification about the period of time in which this would be observed, since event exclusion was done channel by channel. Is that in the -200 to +1200 ms interval of an event?

In Figures 3, 5, and 6, the downward notch at the end of most tracings seems to be an artefact of filtering the average ERP. If these notches are artefacts, rather than brain responses, this should be explained. The legend of Figure 4 gives the interval of interest as 600-1000 ms instead of 600-900 ms.

On page 11 in the Dataset box, remove “32”

Competing Interests: No competing interests were disclosed.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 18 Aug 2015

J. Bruno Debruille, McGill University, Canada

The scientific study of consciousness is extremely difficult. Any serious attempt should therefore be regarded with a positively open mind. The intellectually challenging results of the present experiment, however, are unlikely to pertain to understanding the nature of qualia in the human brain. They rather seem to hint at a social cognition effect.

We acknowledge the possibility that the differences found might not pertain to qualia. We now make this clear at several places. For instance in the discussion, last two sentences of last paragraph of page 12 of the pdf, which reads:

“However, it is very important to point out that *nothing* in the present data can *directly* be related to qualia. The P600 effects of consistency only support spontaneous direct brain-to-brain influences that just *could* be related to consciousness.”

We thus, nevertheless, believe, particularly after our new statistical analyses revealing an effect of consistency at each of the three electrode subsets, that the results point to direct brain-to-brain communications, in addition to social cognition effects, which are now studied and analyzed to address this issue. They appear different from the ERP effects of consistency.

But, we do realize (and acknowledge in the paper) that the brain-to-brain communications might have nothing to do with consciousness. It has to be noted, however, that this possibility would then not be the most parsimonious, since it implies that qualia would have to be underlain by yet another phenomenon than the one responsible for the spontaneous brain-to-brain influences observed.

Design

The data consist in the average amplitude from 600 to 900 ms post stimulus onset of event related potentials (ERP) to complex stimuli selected as “most striking pictures” from the International Affective Picture System (IAPS). EEG recordings were obtained from dyads of socially related participants, simultaneously presented on separate halves of the same screen with a picture that could not be seen by the other participant, even though they were seated side by side and could see each other in the periphery of their visual field. Each participant had to observe the pictures in order to recognize them in a later memory test.

Four different ERP conditions are compared, each consisting of the average of 70 stimuli (minus occasional artefacts at some channels) obtained from the same block. Two of the blocks were introduced to the two participants to consist of identical stimuli simultaneously presented to each of

them, and the remaining two blocks were announced to consist of different sets of pictures. In each pair of conditions, this initial announcement was faithful once and contrary to the actual situation the other time. This allowed analyzing the situation in a 2 x 2 design of Sameness (Identical versus different pairs actually presented) by Belief (believing that the partner was presented with same versus different stimuli).

The recordings, in each participant, were from 28 channels, referred to right ear lobe, not including any EOG dedicated channels. Each picture was presented for 1.0 s with a mean expected inter stimulus interval just below 1.15 s. Therefore, each of the four stimulus block lasted only about 2.5 minutes. The following simultaneous testing phase of the two participants required 28 minutes (280 targets + 280 new items each presented for 3.0 s).

Although the rationale for the study considers qualia and the possibility of common brain signatures, the averaging over different stimuli in the same condition restricts considerably the relevance of the data to the original question of the nature of the qualia and of their physical support in the brain. The authors actually need to extend the concept of qualia to include the knowledge of whether the other person in the dyad is supposed to receive identical or different stimuli, which is very unlikely the dominant subjective experience (qualia) produced by any stimulus. The data are therefore much more likely to pertain to social cognition than to the intended exploration of a physiological substrate for the qualia. Actually, for features of visual perception that do not play a role in the task (for instance by being rare versus frequent events or relevant versus irrelevant), the ERP differences are likely to be idiosyncratic, requiring special statistical technique to detect differences that take different forms in different brains (e.g. Buchsbaum and Fedio, 1969, 1970, for the ERP difference between geometrical patterns and three letter words made of the same number of dots).

ERP results.

Visual inspection of the averages shows that the ERP were negative, relative to the 200 ms baseline, for the full duration of the stimuli in all four conditions for all 12 channels anterior to Cz, and were entirely positive in 6 of the seven posterior channels, at the level of, or posterior to Pz, excluding Pz itself which is mostly negative up to about 400 ms and positive thereafter in all four conditions. Despite the large anterior-posterior inversion in overall ERP polarity, the amplitude differences between conditions remain constant in polarity across all channels.

The differences in condition are most marked between the two Believe Different conditions, with the Actually Same condition (SBd) being positive relative to the Actually Different condition (DBd). In the right hemisphere and posteriorly in the left hemisphere, the two Believe Same conditions (Actually Same and Actually Different, respectively SBs and DBs) were of intermediate amplitudes. In the frontal half of the left hemisphere, however, the ERP to the two Believe Same conditions overlap substantially with those of SBd, all three being less negative than DBd.

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value of all effects involving the three level Condition factor (DBd being excluded).

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Although *ad hoc*, the following explanation may be proposed for the present data in terms of social cognition. In the DBd condition, each partner might be interested in whether the other person is presented with a similar amount of emotion. This would also be so at the beginning of the SBd condition, but the impression would rapidly build that the stimuli, although believed different, would be matched for emotion and therefore this interest in the amount of emotion felt by the other person could fade. This would account for the SDd-DBd difference being the most reliably detected. For the two Believe Same conditions, each partner would not doubt that the other person receives the same amount of emotion, resulting in no difference between these conditions.

Many of the above comments end up casting doubts on the choice of the Different Believed-different (DBd) condition as a baseline condition. We acknowledge that this choice is in itself debatable. On the other hand, the differences obtained between this condition and the others were small (in the order of a microvolt) whereas standard deviations were in the order of 3.5 microvolts. Also, like the other conditions, DBd, was itself a bit noisy. Thus, it could have differed from the other conditions by chance. This could have happened because of the diversity of IAPS stimuli and because there was no speeded decision to make at each trial, which is known to produce sub-optimal ERPs.

One way to deal with these problems was to further improve the signal to noise ratio by doubling the number of trials per condition and thus, by grouping conditions.

This was doable, since after all, to test the fundamental hypothesis that there is some direct brain-to-brain communication that might have an effect on P600s, all that was needed was to see whether conditions that are actually consistent with the belief differed from the conditions where the stimulus displayed to the other participant was not consistent with belief. This is what we decided to do. Therefore, in each participant, we averaged together SBs with DBd (=conditions consistent with the belief) and DBs with SBd (=belief inconsistent conditions).

The new grand averages are shown in the new Fig, 2. The ERPs look less noisy (still without any smoothing) and visual inspection suggests differences between consistency and inconsistency.

Statistical analyses confirmed the significance of these ERP differences (see new results section). Because it was impossible for each participant to see and check whether the stimulus presented to his/her partner was consistent with the belief, which would have been the only classical means by which those differences could have been observed, then, we can say that these results support the existence of direct brain-to-brain communications.

The possibility that the emotional reaction of the other participant to the stimulus could develop, be detected/processed by the subject and impact P600s was extremely unlikely. The time would be too short for the brain of the 1st participant to analyze the stimulus, to organize an appropriate emotional output to the muscles, then, for the muscles to actually move, for the other participant to detect these moves in his/her very peripheral visual-field, to process them and to detect their inconsistency with his own emotion in 600 ms.

To further strengthen this timing argument, we used the small ERP differences that can be detected by the visual inspection of Fig, 2 in the N450 time window, especially at frontal electrode sites (e.g., Fz). We analyzed them. They were significant (now in the new results section), suggesting that the timing was even shorter (about 400 ms), further discarding the emotional account.

These new results are now used in the discussion to support the existence of direct brain-to-brain communications.

The part of the reviewer's comment that we underlined is now addressed by computing the ERPs according to "whether the other person in the dyad is supposed to receive identical or different stimuli"

New statistical analyses were run to test the significance of the small ERP differences found at left anterior electrode scalp site. They were significant, but the scalp distribution of these social cognition effects was quite different from that of the consistency effect (see below).

Correlations

The result section also includes correlations calculated for P600 amplitude differences between conditions. These are reported, in Table 4, only for "the conditions that were the most different from each other, namely, SBd-DBd and DBs-SBs". This justification seems incorrect, given the above table showing no detected difference between SBd, DBs and SBs, and since additional tests of the latter pair does not show any difference at any channel (all $p \geq .073$). Reproducing the scatter plots of Figure 7 confirms that only 14 intact dyads were actually retained (an odd numbered participant followed by the next even number in the data base provided; the rationale for rejecting some participants should have been expressed). The situation, however calls for using the intra class correlation coefficient (ICC) in which no distinction is made as to which member should be A and which should be B, and for which only the common sample mean and common sample variance

are used, resulting in one extra degree of freedom for the test, since only one mean is fitted to the data. When ICC are calculated, the following can be obtained (the sign after the channel name duplicates that of the correlation).

ICC in **SBd-DBd**: 4 channels with $p < .05$

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ICC in **SBs-DBs**: 3 channels with $p < .05$

18 $r = 0.5142$ $t(13) = 2.1617$ $p = 0.0499^*$ O1+

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The other condition differences were not tested. Note that 8/140 (perhaps not independent) correlations tested have $p < .05$, while 7/140 is expected for independent statistical tests when H_0 is true. The critical value of p , with a Bonferroni correction (for 140 independent tests) would be .0018, not reached by any of the 140 tests.

Besides the possibility of there being no true correlation between the dyad members, the negative correlations between the dyad members, observed for the SBd-DBd difference, are counterintuitive. One could call upon disentanglement in which collapsing of the wave function for a particle causes the collapse of the complementary state, even at great distances. But here we have negative correlations on average amplitude differences. The quantum physics speculation not only would dispose of the phenomenon, assuming it is not a statistical accident, as being apparently explained, but this would require further *ad hoc* speculations to explain that the wave function would systematically collapse in the same way in the same person in the given test situation.

If there is a true phenomenon to understand, we should start by questioning whether the negative correlations are mostly associated with SBd or with DBd. Note that since the same variable is used for both members of the dyads, changing its sign would not alter the direction of the correlation. It is unlikely that DBd is the source of the negative correlations since no significant ($p < .05$) correlation is seen in any other difference involving DBd. But the source of the negative correlation is not likely to be SBd either since the other tested difference involving SBd does not replicate the negative correlations. While the negative correlations for SBd-DBd were significant ($p < .02$) at P3 and Pz, it is a positive correlation that is significant ($p < .01$) at P4 for SBd-SBs. Since P4 also gives a significant ($p < .02$) positive correlation for SBs-DBs, the positive correlation for SBd-SBs is more likely attributable to SBs than to SBd (which was involved in the negative correlation).

Setting aside the problem of ascribing the negative correlation to one of the involved experimental conditions, some important insight about social cognition could come from trying to identify the characteristics which defines which member of a dyad would produce a large or positive difference between conditions and which one would produce small or negative differences. Could this, for instance, characterize an implicit cognitive domination-submission attitude? But whether any of these correlations reflects a true correlation remains to be established first. The above discussion

casts serious doubts on this.

Response: We agree, and given, that these correlations

1. **were not based on a *a priori* hypothesis,**
2. **rested on single rather than on the new grouped conditions and**
3. **were not critical to discuss the possibility of a direct brain-to-brain communications,**

we decided to remove them. Thus, they are not in the new version of the paper.

As to the comment:

“The quantum physics speculation not only would dispose of the phenomenon, assuming it is not a statistical accident, as being apparently explained, but this would require further *ad hoc* speculations to explain that the wave function would systematically collapse in the same way in the same person in the given test situation”,

We do not see why this systematicity would be mandatory for the system to detect inconsistency. It seems to us that this could happen in a particular way at each trial. Nevertheless, a real answer to this comment would involve physics far beyond our competences. For instance, what if being closely related to someone depends on some quantum entanglement, as audaciously proposed by some authors? We contacted Basil Hiley. He globally supported the paper but did not comment these issues. We tentatively imagine that the two entangled partners could act on quantum field energy in a similar way when seeing the same stimuli and knowing it and act on that field in different ways when seeing different stimuli while being told they are looking at the same.

We know that anything that is produced by a biological organism tend to be feedback regulated. Accordingly, the brain could be sensitive to some changes in the quantum field energy. It might then also capture something of the effect of the entangled partner on that field. This could lead to inconsistency detection whatever the pattern of the change, provided that this pattern differs from the one expected.

Could that be plausible? We would like to have expert opinions. We hope the paper will be of interests to physicists. However, many of them seem to adhere at Tegmark’s rebuttal of the link between consciousness and quantum field energy (as the one made by Penrose). They no longer discuss such link.

Technical details

In reporting the behavioral data in Table 5 (now Table 3), the misses do not need to be reported, as they should be 70 minus the number of hits (not exactly so here probably because of rounding errors), but the false alarm rate for the 280 new pictures should be added to allow estimating the amount of guessing.

Response: We believe we have to disagree. The amount of guessing for new stimuli is irrelevant since it cannot be used to differentiate the two belief conditions of the study phase. The aim of this memory test was not classical. It was to test the hypothesis of a different encoding in memory according to the conditions of the study phase.

In Figure 2, it is not clear to what the 20 cm distance applies. It would be relevant, however to know

how far apart from each other were the participants and at what distance from the screen were their eyes, so we can appreciate how much they could see of each other.

Response: Thanks a lot for pointing to that figure. There were errors.

The distance from the eyes to the screen was about 60 cm. The piece of cardboard separating the two halves of the screen was 41cm long. The distance between the heads of the 2 participants of a pair (i.e., from the right ear of the participant on the left to the left ear of the participant on the right) was at about 40 cm. We replaced Figure 1 by a photo on which these distances were added, as well as the visual angle corresponding to the width of the stimuli used.

Instead of the first and last half of participants, Figures 5 et 6 could provide the means from the participants on the left and those on the right (even though they are not the same in number), so that any tendency to gaze at the other person at some systematic time after stimulus delivery would be reflected by opposite shifts at F7 and F8. From the data available, there is no systematic group difference if F8-F7 in any or the four conditions, but that tells nothing of the 0-600 ms interval.

Great idea. We did it. Now Fig 5 A & B. And, I did not support the idea of opposed eye movement (included in the results section).

If systematic correlations existed between dyad members, the independence of participants in the ANOVA would not be achieved, so that the degrees of freedom would actually be inflated. This possible bias could be acknowledged, even though the presence of correlations is not very convincing.

We agree. We now mention that brain-to-brain communications jeopardize the independence of participants and that the degrees of freedom could actually be inflated. This is now in the discussion, p 12, 2nd paragraph, starting line 7.

On page 6: the statement “electrodes for which amplitude exceeded +/- 100 mV were discarded” would need clarification about the period of time in which this would be observed, since event exclusion was done channel by channel. Is that in the -200 to +1200 ms interval of an event?

Thanks for that too. There was a 1000-1200 ms non-reject interval. So trials were amplitudes outside of the +/-100 microvolts were within this late time window were kept. This is now mentioned (p6, last paragraph of 1st column, line 6).

In Figures 3, 5, and 6, the downward notch at the end of most tracings seems to be an artefact of filtering the average ERP. If these notches are artefacts, rather than brain responses, this should be explained.

The legend of Figure 4 gives the interval of interest as 600-1000 ms instead of 600-900 ms.

This downward notch at the end of most tracings correspond to the off-effect (i.e., the disappearance of the IAPS picture used as a stimulus), which might also be associated to an eye movement. This is now mentioned in the legend of Fig 2 and 3. We do not think it could be an artifact of filtering. It was probably due to the 1000-1200 ms non-rejection time window.

On page 11 in the Dataset box, remove "32"

Done. Note that this data set now includes the tables for the social-cognition (belief) effect together with that for the consistency effect within the P600 time-window and that for this effect in the N400 time window.

Competing Interests: No competing interests were disclosed.

Discuss this Article

Version 3

Author Response 06 Jun 2018

J. Bruno Debrulle, McGill University, Canada

There is now a follow-up study at :
<https://www.preprints.org/manuscript/201806.0084/v1>

Competing Interests: No competing interests were disclosed.

Version 2

Author Response 22 Jan 2018

J. Bruno Debrulle, McGill University, Canada

Answer of J. Bruno Debrulle to Alexis Lutherborough,

Sorry to answer so late.

....

"If, as you say, colours, and the like, do not exist in the outside world, then it is equally hard to define how they can exist in the brain."

I agree.

It is very challenging to understand how the brain makes up red, or other qualia (and how it does it both during dreams and wakefulness..).

But that is what we have to understand, no?
Isn't it the most fascinating thing of cognitive neuroscience?

I include the link to another paper about a follow-up experiment.:

https://www.researchgate.net/publication/322552239_Event-related_brain_potentials_of_close_others_detect

Best

Bruno

Competing Interests: not competing interest

Reader Comment 06 Dec 2017

Alexis Lutherborough, Macquarie University, Australia

Re: Indexes of Spontaneous Brain-to-Brain Communication

Thanks for the interesting research.

Two comments -

I assume that you are aware of the Grinberg Zulberbaum (1994) paper - "The Einstein-Rosen-Podolsky Paradox in the Brain."

I am not sure about the statement you make in the article that qualia may "propagate." While for physical fields energy may propagate along a metric in space and time, I'm not sure what it would mean to say, for example, that my qualia of "redness" propagates from my brain to another brain?

Furthermore, phenomenal qualia seems to be determined by a complex number of physical relations between the observer and the environment. For example, the experience of phenomenal red is dependent on the observer's optical relation to surfaces in the environment; the spectral properties of light and their relation to the eye; the physiological state of the eye and brain and the higher-order information processing capacities of the brain.

This leaves the frustrating question: what is this thing "redness" that is shared between two correlated brains?

If, as you say, colours, and the like, do not exist in the outside world, then it is equally hard to define how they can exist in the brain.

Having said this, I hope you continue to do research along these lines, as it potentially points to some interesting new questions about how mind relates to the brain.

Regards

Alex Lutherborough
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Competing Interests: No competing interests were disclosed.

Author Response 23 Nov 2016

J. Bruno Debrulle, McGill University, Canada

Just to say that among the 12 reviewers suggested to the editor only one so far accepted to review the paper, which is why it cannot appear in databases such as Pubmed, Scopus etc.

We thus challenge any scientist of the field, especially those who would like to criticize this paper to provide a review.

Competing Interests: No competing interests were disclosed.

Version 1

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J. Bruno Debrulle, McGill University, Canada

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