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Conference Report

Empirical Evidence of Shared Intentionality: Towards Bioengineering Systems Development

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Abstract

This expanded conference paper reports the results of a psychophysiological research study on shared intentionality conducted in 24 online experiments with 405 subjects (208 recipients and 197 contributor-confederates). In this research, we created a bioengineering system for assessing shared intentionality in human groups by modeling mother-neonate dyad properties in subjects during solving unintelligible multiple-choice puzzles. In this model, only the mother (contributor-confederate) knows the correct stimulus and shares this knowledge with the neonate (participant-recipient). The bioengineering system induced interpersonal dynamics in the subjects by stimulating their interactional synchrony, emotional contagion and neuronal coherence. The system collected data by confronting recipients' performance in "primed" and "unprimed" conditions of confederates. These informed contributors knew correct responses only in the "primed" condition and confidently responded on "primed" items. Specifically, in 13 online experiments in mother-child dyads, evidence showed a recipients' performance increase of 48-394%, P-value < 0.001 (62 recipients and 54 confederates) in the “primed” condition of confederates; and in 7 experiments in primary group adults, it showed a performance increase of 143-300%, P-value < 0.002. In experiments in the secondary group, evidence showed a recipients' performance increase only with the UL3 items (a translation of an unfamiliar language, 20 recipients from 41 subjects in experiment No.12). In 3 experiments in 207 secondary group subjects, non-semantic tasks–

SL3 (synthetic language) and US3 (two-color unintelligible symbols)–did not stimulate the effect. We also analyzed data confronting the outcome of recipients' performance in the "primed" condition and random value (possible recipients' responses by chance). Comparing the outcomes of these two data-collecting methods and the sample size of the experiments allow for discussing the research method's validity and reliability. The article also shows four factors' domains that contribute to shared intentionality magnitude.

Keywords
Shared intentionality; social cognition; coherent intelligence; embodied cognition

1. Introduction

This expanded conference paper reports the results of a psychophysiological research study on shared intentionality conducted in 24 online experiments with 405 subjects (208 recipients and 197 contributor-confederates) [1]. Empirical evidence shows the efficiency of coordinated interaction in mother-infant dyads through unintentional movements: social entrainment [2, 3], early imitation [4, 5], and interactional synchrony [6, 7]. The growing body of the literature shows an impact of arousal on group performance [8-10] and spreading emotion from one individual to another organism [11-13], called emotional contagion. Emotion sharing somehow stimulates sharing intentionality in individuals of the "primary group." According to Cooley [14], a "primary group" is a group of members who share a close personal relationship. A common social life marks these groups, shared social routine and interests: activities and culture, and long periods of time spent together. Although there is increasing evidence of consistency between some "motion" and "emotion" concepts, research demonstrating the synergy of the integrative process of all these five concepts is limited. According to Val Danilov and Mihailova [15], ongoing interpersonal dynamics create psychophysiological coherence in dyads (or individuals from the primary group [14]) where movement coordination is cyclically enhanced under ever-growing emotional arousal.

In the reflexes substage of the sensorimotor stage of development (Piaget) or Stage 3 of the Model of Hierarchical Complexity (MHC) [16], newborns do not maintain bilateral communication. According to Tomasello [17], protoconversation in young children appears due to the motive force of shared intentionality. He argued that shared intentionality relies on emotional sharing [17]. Newborns manifest an ability "early intentionality" of unaware targeting [18]. They demonstrate this ability without perception and awareness of self-actions, indwelling in a group with caregivers [18]. A recent theoretical article defined shared intentionality as collaborative interactions in which a recipient organism chooses one relevant stimulus from many irrelevant stimuli due to a contributor organism's intentionality [18]. The newborn and mother share the sensory stimulus of the actual cognitive problem. This social bond enables ecological training of the immature organism, starting at the reflexes substage of development, for processing the organization, identification, and interpretation of sensory information in developing perception [18]. The quality of shared intentionality contributes to ostensive cues for categorizing reality. Immature organisms imbue sensory cues with conventional meanings of the current social environment by collecting statistical information from cascading successful and unsuccessful attempts–statistical learning of shared sensory cues in response to the history of relationships with the social environment. This statistical learning transforms meaningless interactions within the dyad into communication after numerous tentatives in shared events. In such a manner, organisms in the reflexes substage of the sensorimotor stage of development (the 3rd of MHC) begin to categorize the chaos of sensory stimuli. Social interaction shapes organisms' intentionality, promoting similar categorization of stimuli in intimately related individuals with shared social routines and interests [18, 19].

What is the underlying mechanism of "emotional sharing" for shared intentionality? The literature shows that emotional contagion can occur among individuals without awareness of the emotional stimuli' existence [20]. Fishburn et al. [21] accounted for shared intentionality, observing interpersonal neural synchronization in functional near-infrared spectroscopy (fNIRS). They [21] reported coordination of cerebral hemodynamic activation in subjects' pairs when completing a puzzle together in contrast to a condition in which subjects completed identical but individual puzzles. Painter et al. [22] registered pure shared intentionality in the inter-brain experiment in another neuroscience study. They excluded any sensory interaction between collaborators by placing subjects in isolated locations.

Psychophysiological research studies on shared intentionality increasingly grow. In the experiments with 86 subjects, Atmaca et al. [23] showed a joint spatial numerical association of the response codes effect. Evidence showed that numerical (symbolic) stimuli that are mapped onto a spatially arranged internal representation (a mental number line) could activate a co-represented action in the same way as spatial stimuli [23]. The experiments with 115 subjects showed implicit coordination due to sharing intentionality [24]. The experiments with 69 pairs of subjects showed that shared intentionality is the key to perceiving the task as mutualistic (help is a viable option in this game) as opposed to an individual [25]. Val Danilov et al. [26] reported an increase (11%) in 51 adult subjects' performance under the "primed" condition (with clues) for 53 confederates. Other experiments with young children showed a significant increase (above chance) in NT subjects' performance. NT children averaged the relative value of shared intentionality $R = 1.05$ and ND children – $R = 0.33$ [27]. Experiments with 11 groups (of 3 subjects each) showed robust joint commitment due to shared intentionality [28]. Results demonstrate a successful expansion of human social perception [28]. Recent research showed a significant increase (above chance) in ND children's performance compared to NT children [29].

Val Danilov and Mihailova [19] supposed a neuronal coherence agent for shared intentionality occurring during meaningful social interaction even without sensory cues [19]. According to this hypothesis, entangled protein molecules from neurons engage neurons of different organisms in cooperative reactions to shared stimuli. The neurons of a mature organism train the coupled neonate's neurons regarding the fitting reactions to the excitatory inputs of the specific structural organization. This cooperation enables the neonate's neurons to develop a Long-Term Potentiation that links particular stimuli with specific embodied sensorimotor neural networks [19]. Neonates' neurons remember the states' features in the particular environmental condition when organisms are in neurophysiological coherence with the caregiver in the same environmental condition. Therefore, the neonate chooses the same stimulus as the caregiver, learning the stimulus-context bond. The mature organism neurons train the neonate neurons to react in the particular context, indwelling in the same condition under the same stimuli. This training enables the neonate neurons to learn a Long-Term Potentiation that links particular stimuli with specific embodied sensorimotor neural networks [19]. Because any biological system is dynamic, this process can provide ecological learning of organisms.

However, little is known about neurophysiological processes underlying these interpersonal dynamics that promote psychophysiological coherence and what can induce neuronal coherence in different organisms for shared intentionality. The hypothesis of a neuronal coherence agent for shared intentionality occurring during meaningful social interaction even without sensory cues [19] does not explain what environmental features provide non-local cell coupling. The current research aims to study the communication model that shapes shared intentionality and what can induce this neuronal coherence in different organisms in psychophysiological coherence. Section II presents the method of the current research. Section III contains research data from 24 online experiments, their research problem, and their procedure. Section IV presents the results. The limitations and difficulties of this research are discussed in Section V, as well as the research method's validity. Section VI elaborates on all findings.

2. Materials and Methods

This psychophysiological research on shared intentionality contains 24 online experiments with 405 subjects. All experiments adhered to one research paradigm, which relies on emulating the mother-newborn communication model in subjects. This model reconstructs the biological system features that provide ecological learning of newborns in a natural environment. While newborns cannot communicate through sensory cues, they solve cognitive tasks without meaningful sensory interaction with mothers. Only the mother (confederate) knows the correct stimulus and can share this stimulus with the neonate (recipient). That is, the main parameter of the mother-newborn communication model is an absence of meaningful sensory interaction in subjects. Under specific conditions, this model enables the confederate to help the recipient in ecological learning. If this model was emulated in subjects, the recipient could choose shared stimuli by interacting with the subject-confederate without sensory cues. We developed the bioengineering system to emulate the mother-newborn communication model in subjects and assess the recipient's performance. At the same time, they solved identical tasks with the confederate without communication via sensory cues between them. The research design contained the following methodological components that, in brief, show the very soul of research:

1. Assessing objective. Shared intentionality was evidenced by increases in performance above baseline, shaped by recipients' answers without a clue to the confederates ("unprimed" condition). This increase was chosen to serve as an indicator. The primary indicator was the superior number of intuitive responses comparing results with "unprimed" conditions. We also compared it with a random choice value.
2. The object of influence. The bioengineering system stimulated subjects by employing human-computer interaction for shaping the mother-newborn communication model. As we supposed, this would induce neuronal coherence in both recipients and confederates when solving unintelligible tasks.
3. Stimuli. The two-component stimuli encouraged neurophysiological coherence. The first component was unintelligible test items. By asking the unintelligible tasks, the bioengineering system put the participants in conditions where they were forced to muster all their properties (explicit or implicit ones). It stimulated subjects to choose the correct option via

shared intentionality since the lack of other meaningful interactions did not give them another possibility for correctly answering. The unintelligible task in the "primed" condition were meaningful symbols for confederates and meaningless ones for the subjects. A single harmonic oscillator was a second component of stimuli. The low frequency-pulsed electromagnetic field (LF-PEMF with wavelengths of 700 and 400 nm) stimulated interpersonal dynamics and long-term corticospinal excitability. These two intersected processes provided neurophysiological coherence in subjects for emulating the communication model. As we supposed, the interpersonal dynamics and long-term corticospinal excitability would provide cell coupling at the neuronal level. The two hypothesis attempt to explain the nature of this cell coupling: the hypothesis of the entangled protein molecules in neurons [19] and the idea of the LF-PEMF effect on A(2A) adenosine receptors.

4. Data collection process. The value was derived from two modes of data collection: the difference between the number of correct subjects' responses on unintelligible items and (i) results in the "unprimed" condition of confederates, and (ii) random choice value. The system collected data by confronting recipients' performance in "primed" and "unprimed" conditions of confederates. These informed contributors knew correct responses only in the "primed" condition and confidently responded on "primed" items. Shared intentionality is an implicit process; the only increasing outcome showed this implicit collaboration of the participants. The increased outcome separated teamwork from independent individual action (they could not improve performance independently due to unintelligible tasks).
5. Subjects: recipients and confederates. The research included 405 neurotypical subjects. The original data set contains information about 405 participants, including tests score files stored, age, and education. Subjects were required to solve unintelligible test items in the forced choice design paradigm. The subjects in the experiments of block 1 (see Table 1) were mothers and children. The subjects in experiments 2 and 3 (see Table 1) were students randomly divided into two groups: recipients and confederates. All procedures followed relevant ethical principles for research involving human subjects in the Declaration of Helsinki. The research protocol was approved by the SlA "Klinika Piramida 3" (Latvia), reg.No.LV40103954226.
6. Bioengineering system. We created a bioengineering system for registering shared intentionality in human groups by emulating the mother-neonate dyad properties in participants during solving unintelligible multiple-choice puzzles. The bioengineering system stimulated interpersonal dynamics in the subjects and induced their neuronal coherence. It employed human-computer interaction that stimulated interpersonal dynamics by the two-component stimuli: the unintelligible tasks and LF-PEMF with wavelengths of 700 and 400 nm. This bioengineering system shaped the "mother-newborn" model in the dyads for detecting meaningful interaction within the pairs via shared intentionality since this communication model eliminated other meaningful interactions. It employed two instrumental components: a smartphone and original software in a server. The smartphone was an interface for test puzzles and representing data output, and a sensor for the data input. At the same time, it generated LF-PEMF with wavelengths of 700 and 400 nm. The server processed a signal from the input to the output. The software provided an interface for users to enter data and process collected data, saving it on the server. The flash-chat of the bioengineering system algorithm for the research bioengineering system is presented in Figure 1.

Table 1 Results of 24 experiments.

Group	**The Ratio of Correct Responses**					
	Ratio	***Task UL, %***	***Task SL, %***	***Task US, %***	χ^2	***P-value***
1. Dyads, 116 subjects	Rb	48	394	123	16.142	<0.001
	Rch	90	42	32		
2. Primary group, 41 subjects	Rb	143	300	127	13.493	<0.002
	Rch	216	28	20		
3. Secondary group, 248 subjects	Rb	–	–8	3	0.083	<0.975
	Rch	–	31	–9		
	Rb	133	–	–	250.624	<0.001
	Rch	380	–	–		

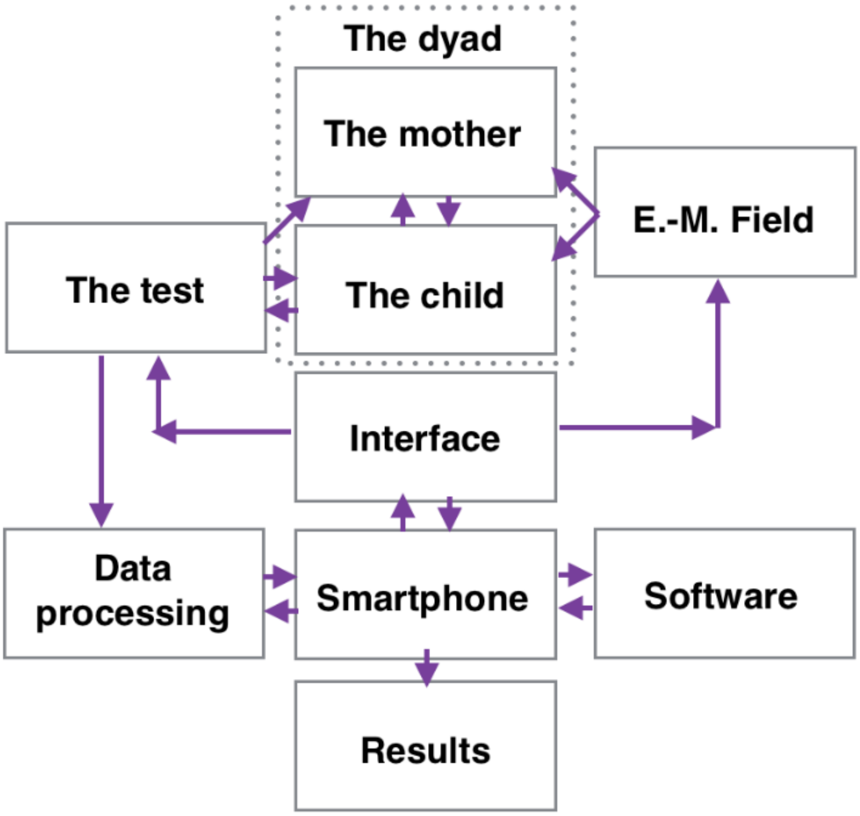

Figure 1 The flash-chat of the bioengineering system.

3. Experiments

In 2020, we conducted 24 experiments with 405 subjects to test the MCI hypothesis of whether this effect also appears online. The research problem of these 24 online experiments was whether or not unprimed recipients showed a more significant accuracy level when they completed intellectual tasks simultaneously with confederates primed with the correct answer. Would the quality of shared intentionality help recipients solve unintelligible items without communication between participants in psychophysiological coherence?

The within-subjects paradigm was applied to verify the difference between the correct responses of the recipients (unprimed subjects) to the "primed block" and "unprimed block" of tasks. Specifically, subjects (unprimed recipients and primed confederates) with their computers joined the experiment through an online conference. They were also asked to prepare their mobile phones to complete the experimental tasks during the online conference by connecting to the experiment's website via their smartphones. As soon as they all were online, experimenters divided subjects into two groups (recipients and confederates) and informed them about the task.

Then, all subjects were asked to use their smartphones to contact the experiment's website to complete the test. Testing began simultaneously when all subjects were connected via their mobiles to the website. The experiment design provoked emotional arousal due to the experiment's unusual situation and rhythmically changing the red/purple colors of the mobile screens. Many studies on emotional arousal in learning show increased participants' cortisol levels during experiments [16]. Unintelligible tasks also contributed to emotional excitement in subjects and the participation of strangers (experimenters) in these performances [16]. Interactional synchrony in subjects was stimulated by rhythmically changing colors of the mobile screen (80 bpm), which was identical for all. In such a manner, we stimulated the interpersonal dynamics in subjects. As we believed, this LF-PEMF (with wavelengths of 700 and 400 nm) also stimulated long-term corticospinal excitability.

During testing, the website simultaneously presented to all subjects 10 items. The all tasks design was the same for all subjects (recipients and confederates)–all subjects saw the same picture with a similar mapping of the task and its answer options. The design of each task promoted the same geometrical navigation on the screen for all. The mapping of Unfamiliar Language (UL) task presented 10 answer options in one line on the screen of the mobile phones. The mapping of the unfamiliar Synthetic Language (SL) task presented 8 answer options located on the square's perimeter on the screen. The mapping of Unintelligible Symbols (US) task presented on the screens 4 answer options located on the square's corners. That is, each task had the same for all subjects' task-options mapping design, and answer options were in the same place on the mobile phone screens for all subjects (recipients and confederates). In such a manner, we designed the same geometrical point of the correct answer on the screens for all recipients and confederates. Screenshots of the web interface are presented in Figure 2.

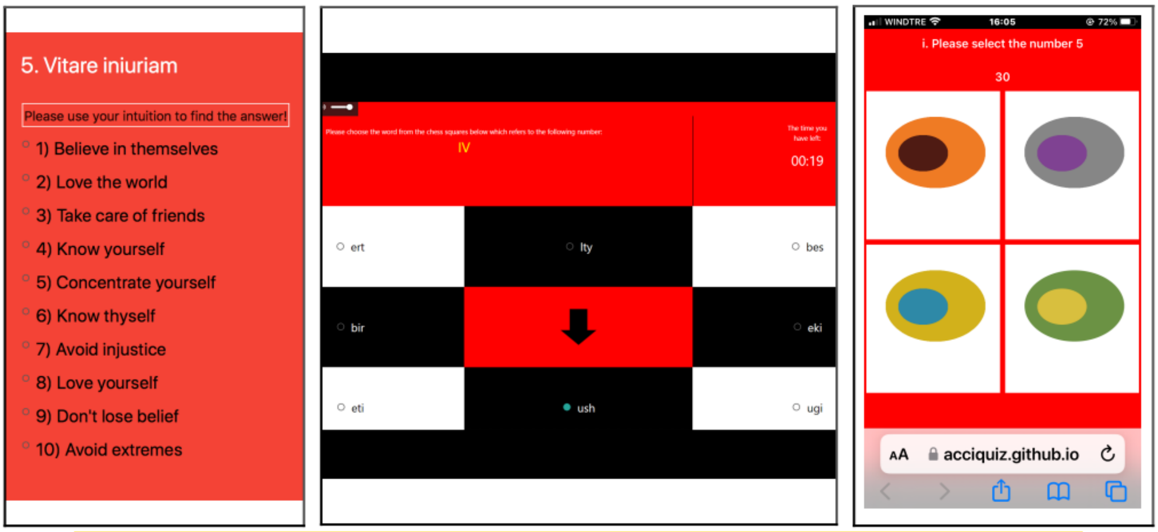

Figure 2 The screenshots of the items, from left to right: UL, SL, and US tasks.

The confederates were asked to follow hints on the correct answers for solving tasks. They received hints on all even-numbered items (2-4-6-8-10)–"primed block" of tasks. The unprimed tasks for the confederates were all un-even (odd-numbered) items (1-3-5-7-9)–"unprimed block" of tasks. They did not receive instructions on odd-numbered items, they just guessed answers. In evaluating the outcome, the "unprimed block" of uneven items (1-3-5-7-9) became the baseline of the experiment. Recipients did not receive any instruction on any item; the unprimed block (1-3-5-7-9) and the primed block (2-4-6-8-10) were unintelligible tasks for them.

The result was estimated by two values: (1) *Rb* – the ratio between the correct responses of the recipients (unprimed participants) to the "primed block" and "unprimed block" of tasks, (2) *Rch* – the ratio between the correct responses of the recipients to the "primed block" and possible responses by chance.

3.1 Experiments with Translation of Unfamiliar Language (UL)

UL1: We conducted 6 online experiments with 44 subjects (22 children M = 9 years); we tested subjects who were typical representatives of the primary group. The task was to choose the correct translation of an unfamiliar language (Latvian language for Italian and Russian speaking) from 10 variants from the list of 10 options. Before the experiment, we asked the subjects if they spoke the investigated language to make sure that this language was unfamiliar to them. Each dyad was divided into recipient (a child) and primed confederates (her mother). They were asked to avoid any communication between them during testing. Dyads were required to translate unfamiliar foreign words themselves (independently) by choosing one correct translation from 10 variants in their native language in a congruent design and, with the opposite task, in an incongruent one. The confederates received correct answers on the "primed block" of tasks (all even items 2-4-6-8-10). These online experiments in different languages found evidence of an increase of *Rb* = 48% in a group performance between the "primed block" of tasks and "unprimed block" and an increase of *Rch* = 90% above chance in the "primed block," the results are in Table 1.

UL2: The same tasks under a similar procedure were tested with 24 adults: students (M = 17) and groups of friends (M = 31 years). These subjects could not be attributed as typical representatives of the primary group; nevertheless, many of them stayed in a coordinated state of social entrainment with their fellow, as we believe. We estimated them as the primary group. The subjects of five experiments No. From 7 (18/04/2020) to 11 (12/05/2020) had been studying together for many years. These online experiments with different unfamiliar languages (Latin language for English, Latvian and Russian speaking) found evidence of an increase of *Rb* = 143% in a group performance between the "primed block" of items and "unprimed block", and an increase of *Rch* = 216% above chance in "primed block," the results are in Table 1.

UL3: We repeated the same procedure in experiment No. 12 (12/05/2020) with subjects who were 41 second-year university students (M = 20 years). They had known each other not more than two years and it seemed difficult to define their biological state as close to the social entrainment. We attributed them to the secondary group. The results of 4 students were excluded from the outcome, since they spoke the examined language–Italian language for English, Latvian and Russian speaking. The online experiment No.12 shows evidence of an increase of *Rb* = 133% in a group performance between the "primed block" of items and the "unprimed block", and an increase of *Rch* = 380% above chance in the "primed block," the results are in Table 1.

3.2 Experiments with a Rebus from Synthetic Language (SL)

SL1: We conducted 4 online experiments with 23 children (M = 9 years) and 19 mothers (M = 40), specifically 19 families. The task was choosing the correct version of a rebus from 8 options around the square's perimeter. The rebus consisted of unintelligible symbols from synthetic language created especially for this experiment. These online experiments found evidence of an increase of *Rb* = 394% in a group performance between the "primed block" of tasks and "unprimed block", and an increase of *Rch* = 42% above chance in the "primed block", the results are in Table 1.

SL2: We tested the same tasks with 7 adults (M = 18): students in the last year of high school. We believe they were in a coordinated state of social entrainment because of many years of studying together under the same schedule. We estimated them as the primary group. These online experiments found evidence of an increase of *Rb* = 300% in a group performance between the "primed block" of tasks and the "unprimed block", and an increase of *Rch* = 28% above chance in the "primed block", the results are in Table 1.

SL3: We tested the same tasks with 56 adults (M = 20): students in their second year of university. We estimated them as a secondary group. These online experiments did not find evidence of *Rb*'s increase in a group performance between the "primed block" of items and the "unprimed block." At the same time recipients' outcome in both conditions was *Rch* = 28% above chance, the results are in Table 1.

3.3 Experiments with Unintelligible Symbols US

US1: We conducted 3 online experiments with 17 children (M = 9) and 13 mothers (M = 40); specifically, there were 13 families. Their task was to choose the two-color symbol related to one of the natural numbers from 1 to 5 among four options. In each item, four answer options (different two-color symbols) were located in the corners of the square's perimeter. These five two-color symbols were created specifically for this experiment. They consisted of two colored circles (one in the other). The meanings of these unfamiliar symbols were unintelligible to subjects. Experimenters asked subjects to solve the tasks by applying different strategies. Recipients (unprimed subjects) were asked to guess the correct answer intuitively. In contrast, confederates were asked to solve the problems rationally, following hints on the correct answer. These online experiments found evidence of an increase of *Rb* = 123% in a group performance between the "primed block" of items and "unprimed block", and an increase of *Rch* = 32% above chance in the "primed block", the results are in Table 1.

US2: We conducted 1 online experiment with 10 friend adults (M = 31): 4 confederates and 6 recipients. Their task was the same as of US1: to choose the two-color symbol related to one of the natural numbers from 1 to 5 among four options. Experimenters asked subjects to solve the tasks by applying different strategies. Recipients were asked to guess the correct answer intuitively. In contrast, confederates were asked to solve the problems rationally, following hints on the correct answer. In such a manner, we tried to stimulate recipients not to use any rational strategy (to guess the correct answer intuitively). In contrast, we tried to motivate confederates to think about an answer (to solve the problems rationally) but not only push the correct option button. These online experiments in different languages found evidence of an increase of *Rb* = 127% in a group performance between "primed block" of tasks and the "unprimed block", and an increase of *Rch* = 30% above chance in the "primed block", the results are in Table 1.

US3: We conducted 2 online experiments with 151 students (M = 19) from the first year of the university. We estimated them as a secondary group. They knew each other for not more than a few days (if they knew each other, they did not meet because of the online university course), and it seems impossible to define their biological state as close to the social entrainment. Their task was the same as of US1: to choose the two-color symbol related to one of the natural numbers from 1 to 5 among four options. Experimenters asked subjects again to solve the tasks by applying different strategies. Recipients were asked to guess the correct answer intuitively. In contrast, confederates were asked to solve the problems rationally, following hints on the correct answer. These online experiments in different languages found evidence of an increase of *Rb* = 3% in a group performance between the "primed block" of tasks and the "unprimed block." Their results *Rch* were below chance, see Table 1.

4. Results

The 20 experiments in subjects from the primary group include 13 experiments in dyads (with 58 mothers and 68 children), and 7 experiments with 41 adults. The results are presented in Table 1. Samples 1 and 2 of the first and second lines of Table 1 are the mother-children dyads and adult groups with a typical social routine story of many years, so-called the primary group [14]. The 3rd sample–the third line of Table 1–is unfamiliar adults. We provided a statistical test of whether group means within each line (group assemblage with similar extant social entrainment–sample) were equal.

The 4 experiments in subjects from the second group with 248 adults (sample 3) showed the shared intentionality effect only in the UL3 task (a translation of an unfamiliar language). Other experiments in a secondary group with the tasks SL3 and US3 did not show the effect.

There are several abbreviations to note: UL – the experiments with the translation of an unfamiliar language; SL – the experiments with a rebus from unknown symbols of a synthetic language; US – the experiments with two-color round symbols; *Rb*, equation (1) – the ratio between the correct responses of the recipients to the "primed block" and "unprimed block" of tasks; *Rch*, equation (2) – the ratio between the correct responses of the recipients to the "primed block" and possible responses by chance; *Mp* – mean primed; *Mb* – mean baseline (unprimed); *E* – estimated by chance; *O* – observed results (both *Mp* and *Mb*); *P*-value – the significance of results, rejecting the null hypothesis; and values of the Chi-squared distribution is χ^2.

5. Discussion

5.1 Method's Validity and Reliability

Rigorous research designs require reliable and valid psychometrically sound measurement tools to maintain the integrity of study findings [30]. Confronting results with estimation from another valid method is one of the strategies for verifying the method's validity. The research outcome contains two data collecting methods: (i) comparing results in "primed" and "unprimed" conditions, and (ii) comparing results of the "primed" condition and random choice value. The obtained data in both designs are consistent with the hypothesis and relevant to each other. Comparing the outcomes of the two methods reveals the data parity that may mean the methods' validity.

According to Standards for Educational and Psychological Testing [31], test validity refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests. In social science, constructs refer to various phenomena and properties on an abstract level of consideration. According to Uher [32], while constructs cannot be measured, construct indicators (referents) can. Because constructs and their indicators constitute different entities. Indicators are neither the construct nor specific quantities of it [32]. Quantitative information about construct indicators is encoded in so-called manifest variables. Empirical structures underlying the numerical values of various manifest variables are statistically analyzed and modeled in fewer (or even just one) synthesized variables, called latent variables [33]. The latent variables are stimulated to maximize the fit to the statistical assumptions specified in the research problem. These psychometrically modeled data reflected quantitative information about the construct. Therefore, measurement processes can be established for many concrete entities chosen as construct indicators [33]. For instance, shared intentionality is studied indirectly through its property (a correct response by guessing) chosen to serve as indicator. The current research method on shared intentionality used the interrelations between manifest and latent variables (between insights in item responses and shared intentionality). These psychometrically modeled data reflected quantitative information about the construct of shared intentionality. The score of item response (Yes/No) in the multiple choice item of 'forced-choice' research design is the psychometric unit that describes properties of numerical data obtained in the "shared intentionality" testing synthesized through statistical modeling. The reviewed research likely provided a valid method since the presented empirical data and the theory support the interpretations of test scores.

Finally, in psychometrics, item response theory (IRT) considers validity in terms of the item concept. The IRT models the response of each subject of a given ability to each item in the test [34]. The term item is generic, covering all informative items (e.g., multiple-choice questions). The type of IRT model depends on the research question, field of study, and how many item parameters are estimated and held constant. The current research paradigm implied unintelligible items–questions without rational responses that only an outside expert could solve (the caregiver). Therefore, the item discrimination and difficulty could not be the item parameters. This IRT analysis applies a one-parameter logistic model since the guessing (insight) parameter was only studied. The IRT is based on the idea that the probability of a correct/keyed response to an item is a mathematical function of person and item parameters. Information is also a function of the model parameters. According to Fisher information theory [35], in the case of the one-parameter logistic model, if the n items are independent, then the Fisher information n times greater than the Fisher information of a single sample and is inversely proportional to the probability of a correct answer multiplied by the probability of an incorrect answer (Equation 4). The standard error of the estimate $SE(\Theta)$ is the reciprocal of the test information at a given trait level (Equation 5). In mathematical statistics, the Fisher information approach measures the amount of information with the meaning of the variance of the score of the specific research design. The research method simulated items in 10 trials with the probability of the correct response of 0.25 (the highest probability in 4 options design). According to the Fisher information, these data yield the standard error of the estimate $SE(\Theta)$ = 0.137, which is relatively small. The small standard error of the estimate indicates a more valid test [36]. This outcome does not validate the particular interpretation of the test scores; it shows that the selected method fits the research purpose.

Reliability shows how far the method will produce similar results, assuming nothing else has changed [37] and presenting aspects of coherence, stability, equivalence, and homogeneity [38, 39]. Stability reliability is tested when the attributes under study are not expected to change [30]. However, shared intentionality emerges not in all interpersonal dynamics and not always to the same extent [40]. The biological system is dynamic; it evolves in time and space under endogenous and exogenous factors. Further discussion in this section shows that the factor analysis should be done for leveling dynamic input. This procedure would level the input data deviation of the value of shared intentionality due to the biological system development in a rapidly changing environment. This data processing also contributes to the method's reliability since it provides outcome soundness.

5.2 Endogenous and Exogenous Factors

Shared intentionality emerges in individuals of the primary group not in all interpersonal dynamics and not always to the same extent. Four factors' domains contribute to facilitating or depressing shared intentionality magnitude. According to Val Danilov [41], shared intentionality depends on the psychophysiological conditions of both sides of the protoconversation, the most influential of them are presented in Figure 3.

	Endogenous factors	Exogenous factors
Facilitating	1) Social entrainment. 2) Normal level of hormones concentration in children. 3) An increase of oxytocin concentration in woman during the menstrual cycle from the early follicular phase to ovulation.	1) Exciting stimuli for emotional arousal. 2) Exciting stimuli for interactional synchrony. 3) Intellectual stimuli. 4) Pleasant social stimuli 5) Motivation
Depressing	1) Low oxytocin concentration in woman during the menstrual cycle from ovulation to the mid-luteal phase.	1) Too exciting emotional stimuli. 2) Depressed psycho-physiological state.

Figure 3 Endogenous and exogenous factors for facilitating or depressing shared intentionality

5.3 Limitations

Limitations of data analysis. When observing a psychological construct, it is not always clear what statistics can test. In psychometrics, measurements aim to identify a latent variable that cannot be directly observed. The Standards for Educational and Psychological Measurement gives the following statement on test validity: "Validity refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests [31]". In other words, a test is non-valid unless it is used and interpreted as intended. Therefore, one of the features of test validity in psychological measurement is complete knowledge about latent variables–knowing factors of a studied psychological construct. Indeed, each individual is a dynamic biological system influenced by many endogenous and exogenous factors (see subsection 5.2 Endogenous and Exogenous Factors). So, no one can ever know what is behind the observed scores unless it is controlled all factors of the observed psychological construct at the moment of the experiment.

Analysis of variance (ANOVA)–as a collection of statistical models and their associated estimation procedures–provides a statistical test of whether two or more population means are equal. Because knowledge about latent variables is incomplete in psychological research, ANOVA shows us a little about the difference between two or more population means by testing the difference between two or more group means. No one can know what is behind the observed scores of a group and how they correlate with those of the population unless it is identified and controlled all endogenous and exogenous factors of the observed psychological construct at the moment of the experiment. The problem is that we study the psychological construct to identify its factors. Even before knowing all factors, we need to employ statistical tests in gradually developing knowledge about the psychological construct. Still, statistical analysis can extract some information from psychological research data. One of the ANOVA test properties helps determine the significance or randomness of the results of an experiment. In the case of testing a psychological construct whose factors are not completely defined yet, this property of ANOVA can yield information. However, it shows us no more than the randomness of the results that random factors cause the observations.

For instance, another intelligence research (another psychological construct) observed an association between individual intelligence and group performance. It argued that getting many smart people in a group does not necessarily make a smart group [42]. In assigned cognitive tasks of different natures, the collective intelligence study concluded that neither the average intelligence of the group (average of the individual IQ coefficients) nor maximum intelligence (the highest IQ among individuals in the group) was a good indicator to predict intelligence of a group [42]. This study argued that social skills and the distribution of conversational turn-taking might matter more in the group's intelligence than its members' individual brilliance [42]. In the case of another psychological construct, the test scores do not so much depend on latent variables observed by research; taking another sample or the same but in another context does not allow us to know more about the association between individual and group intelligence. This test gives little knowledge about the differences among means unless it is revealed all factors and is controlled all variables for interpretation in the way it is intended. The scores analysis does not show us more than the randomness of the results. What we can argue now about intelligence in groups by analyzing the differences among means is that the data on social skills and the distribution of conversational turn-taking is above randomness.

The main purpose of the current research was to observe empirical evidence of shared intentionality during the collaborative performance of related individuals. In the case of testing shared intentionality (by asking unintelligible questions), the experiments measured shared intentionality–implicit interpersonal connectivity–while participants answered unintelligible questions. Guessing was the only possibility to enable shared intentionality between participants since any rational strategy in answering unintelligible tasks could change the outcome. In this case, guessing does not mean randomness. On the contrary, it was precisely what the research design asked subjects and measured. Again, because any rational strategy in answering unintelligible tasks could change the outcome of shared intentionality assessing, guessing was the only way to react that research could propose to subjects while they answered unintelligible tasks. Therefore, shared intentionality was inferred by choosing the relevant sensory stimulus (shared within the confederate and the recipient). This was evidenced by increased performance above the levels expected by chance and by baseline without a clue to the confederates. This increase was chosen to serve as an indicator. From this perspective, the main concern in measuring shared intentionality was distinguishing intent responses to items from randomly generalized outcomes by subjects. We knew the only factor of shared intentionality for invited groups–their social entrainment. The mother-children dyads and adult groups with a similar social routine of many years were attributed to the primary group [14], samples 1 and 2 of the first and second lines of Table 1. Unfamiliar adults were attributed to the secondary group, sample 3–the third line of Table 1. We provided a statistical test of whether group means within each line (group assemblage with similar extant social entrainment–sample) were equal. Due to an analogy with another psychological construct (noted above collective intelligence), what we could argue about shared intentionality by analyzing the differences among means was only that scores were higher than chance, and the group outcomes were not random, which may mean that the effect of shared intentionality was registered.

In this research, we used measures of one-way ANOVA. We have used a chi-square test to compare the proportion of correct answers across tasks in the mode of data collection that compares the difference between the number of correct subjects' responses on unintelligible items and results in the "unprimed" condition of confederates (Rb). When comparing two groups, a t-test is preferred over ANOVA. However, when we have more than two groups (as in our case), the t-test is not the optimal choice because a separate t-test needs to perform to compare each pair. In parallel, the experiments compared these outcomes with the random choice value (Rch) because we were collecting a large sample size. Even though there is no correlation between performance in different types of tasks (UL, SL, US), the outcome shows significantly increasing performance. At the same time, participants simultaneously solved identical tasks and confederates received clues. So, using dual modes of data collection, experiments also avoided the randomness of the results and supported method validity. As noted above, the ANOVA test helps determine the significance or randomness of the results of an experiment. Combining the data collection modes in current experiments bears the same purpose–to exclude randomness. While the current research data collection and ANOVA solved the same problem of randomness, we also used ANOVA by computing the p-value to support method validity. The p-value is less than 0.05; therefore, the Null Hypothesis of an implicit collaboration absence among the participants should be rejected.

Post hoc analysis consists of statistical analyses usually used to uncover specific differences between three or more group means when an analysis of variance (ANOVA) test is significant [43]. Psychological research can create a multiple-testing problem because each potential analysis is effectively only a statistical test that, in this case, can show us no more than the randomness of the results [44]. Post hoc analysis that is conducted and interpreted without adequate consideration of this problem is sometimes called data dredging by critics because the statistical associations that it finds are often spurious [44]. We did not provide the post hoc analysis because, to our mind, it could not yield more information about samples than we have inferred–results are significant. Further, more specified research needs to explore different aspects of the mother-newborn communication model, providing a measurement of post hoc statistical power.

Finally, the data analysis is limited because the research problem concerns a psychological construct of shared intentionality, which factors still need to be identified and controlled. Further research needs to explore different aspects of the mother-newborn communication model. However, even though the data analysis is limited, the outcome evidences the shared intentionality effect.

5.3.1 Limitations Due to Life Experience

The limitations of the unfamiliar language task (UL) and synthetic language task (SL) are grounded in the life experience of subjects. Translation of an unfamiliar language (or solving a rebus) is challenging; however, subjects could casually hear foreign words in the past and/or create associative relationships with words/symbols they already knew. This implicit knowledge cannot be completely excluded from the outcome. Even though we selected unfamiliar foreign words (as it seemed to us) verifying this linguistic task with a control group, did not exclude such cultural influence on subjects' results. Possible experience and/or associative relationships between words/symbols could adjust the results. Nevertheless, it seems uncontroversial to say that young children acquire knowledge through a communication environment: language and other communicative signs. The current paper explores the modalities of social interaction that help organisms to assimilate knowledge. Therefore, we propose considering this outcome because language is a typical communicative cue for children. It is possible to suppose that a communicative environment–symbols' domain–can enhance non-perceptual interaction. We suggest mentioning this since the control group did not show any difference in results between even-numbered tasks and un-even (odd-numbered) tasks, testing them under unprimed conditions. This control group outcome may mean that the set of foreign words was unfamiliar for the particular subjects of the control group and may provide hope that this was a spread case also for other subjects. In contrast, the tasks with two-color round symbols (US) could create less association with previous knowledge in recipients. From this perspective, the task US could show pure non-perceptual social interaction. These limitations can describe the difference in results between UL, SL, and US tasks in different groups. For instance, the primary group (dyads and adults) perform better linguistic task UL than the tasks with rebus from unknown symbols SL and two-colored symbols US, showing in the UL better results above chance.

It seems uncontroversial to say that the third task US with two-color round symbols excluded participants' experience (previous knowledge) from problem-solving to a greater extent. Comparing results between different tasks and groups shows the lowest increase of the *Rch* coefficient – the ratio between the correct responses between the "primed block" and responses by chance.

One of the research difficulties was to ensure the intentionality of the primed subjects (confederates), since the only following the instructions on the correct answers was not too exciting for them. We expected their mental collaboration instead of indifferent action in choosing the correct option. Therefore, we created a special game for confederates depending for each experiment depending on their personal interests. Although, in the sense of a person's unexpected choice, none can be sure of what to expect from a person, within reasonable limits. Human uncertainty creates a problem for any research in psychology. Frankness, sincerity and involvement in the experiment are one of the most influent factors of the testee's impact on the research results. The experimenter can never exactly know the real intention and involvement of the examinee. We believe that the difference in the outcomes of the different groups also shows the extent of the subject's involvement in the process.

The outcome was questioned: whether the correlation of results between teams of subjects (recipients and confederates) is an evident pattern, or it happened by chance. The hypothesis evaluation using the *P*-value shows the significance of results in experiments with dyads and adults attributed to the primary group. The 20 experiments with subjects from the primary group show: (i) the *P*-value < 0.001 in 13 experiments in dyads; and (ii) the *P*-value < 0.002 in 7 experiments in adults. The significant result implies that the performance was significantly greater due to priming than expected by chance. Thus, the prime resulting transmission of correct sensory cues from the confederate to the recipient. We believe this outcome is statistically significant, rejecting the null hypothesis of the absence of shared intentionality in subjects attributed to the primary group.

5.4 Unexpected Results

We did not expect the coherent intelligence effect in experiments with subjects of the second group, and we did not find it in the experiments with the SL3 (one experiment with 56 adults, M = 21) and US3 tasks (2 experiments with 151 first-year students, M = 19). Surprisingly, the outcome of the experiment No.12, 12/05/2020 with the task UL3 (an unfamiliar language) was very high; this experiment's Chi-squared distribution and P-value are very significant. This deviation from the expected result for this team was 380% higher than the probability of a random choice. We tested these subjects before the experiment on the knowledge of the examined language, and the results of 4 students were excluded from the outcome, since they speak it. Other subjects did not speak this language at all. Following the secondary group definition, we rated this team as the secondary group, while they showed results as members of the primary group. The result of experiment No.12 led us to additional study the history of these students' relationships and the formation of their teams. Additional information at the analysis stage of the results showed that these second-year students had visited university facilities daily before the pandemic in 2020. They followed the same social rhythm for two academic years before the experiment. While studying at the university, they also completed an additional team training program to increase inter-group cooperation. To our mind, the UL3 outcome means that these subjects had more close social cooperation between them than we thought at the moment of the experiment. This additional information may be useful for understanding why these subjects from the second group (as we thought earlier) also showed a significant accuracy in translating an unfamiliar language, as if they were members of the primary group. We believe that the results of experiment No.12 (UL3) provide an opportunity for further research on the formation of close social bonds in groups that can also promote the more precise determination of the primary group's criteria. Further research on how the modality of communication can affect the message's understanding, even if the language of the message is unfamiliar to the recipient, can also develop knowledge about inter-group cooperation. The results of other teams with subjects of the second group in tasks SL3 and US3 supported our expectations that there should be no coherent intelligence effect in the secondary group. The unexpected result in UL3 does not reject the significant outcomes of experiments in dyads (UL1, SL1, and US1) and adults from the primary group (UL2, SL2, and US2).

5.5 Application Perspectives

The article shows a new direction for further research on the mother-newborn communication model. It reveals empirical evidence that the performance was significantly greater due to priming than "unprimed" condition and than expected by chance. Likely, interpersonal dynamics (promoted by emotional arousal and interactional synchrony) can promote psychophysiological coherence and, together with LF-PEMF, induce neuronal coherence in different organisms for shared intentionality.

Knowledge about neurophysiological processes occurring during non-perceptual interaction may reveal perspectives in a wide range of applications in bioengineering. Some examples of further development of bioengineering systems are assessing cognitive development in preverbal children, smart prosthetic limbs, and human-computer non-invasive brain-computer interaction. In addition, artificial intelligence is a crucial issue in the 4th industrial revolution. The ability to integrate (contactless) the human brain with a computer may contribute to another approach to artificial intelligence, creating a bridge to the next stage of human progress. Understanding this social interaction modality can highlight a systematic problem in social sciences. Research studies on children's development usually do not consider caregiver-infant non-perceptual interaction when exploring children's behavior. However, knowledge about crucial experimental variables defines research design. Understanding crucial components (e.g., the psychophysiological processes) of social interaction determines the requirements for and imposes restrictions on the experiment's variables.

6. Conclusions

We conducted 24 online experiments with subjects of the primary group (20 experiments, 157 subjects) and subjects of the second group (4 experiments, 248 subjects). The unprimed subjects (recipients) attributed to the primary group showed a more significant accuracy when they completed a thought task in the presence of confederates (primed subjects from the same group) who were simultaneously primed with the correct answer to the same task. We believe that the outcome of the primary group (dyads and adults) is statistically significant, rejecting the null hypothesis (absence of shared intentionality).

Specifically, in 13 online experiments in mother-child dyads, evidence showed a recipients' performance increase of 48-394%, P-value < 0.001 (62 recipients and 54 confederates) in the “primed” condition of confederates; and in 7 experiments in primary group adults, it showed a performance increase of 143-300%, P-value < 0.002. In experiments in the secondary group, evidence showed a recipients' performance increase only with the UL3 items (a translation of an unfamiliar language, 20 recipients from 41 subjects in experiment No.12). In 3 experiments in 207 secondary group subjects, non-semantic tasks–SL3 (synthetic language) and US3 (two-color unintelligible symbols)–did not stimulate the effect.

We also analyzed data confronting the outcome of recipients' performance in the "primed" condition and random value (possible recipients' responses by chance). Comparing the outcomes of these two data-collecting methods and the sample size of the experiments allowed for discussing the research method's validity and reliability. It reveals empirical evidence that the performance was significantly greater due to priming than in the "unprimed" condition and than expected by chance. Likely, interpersonal dynamics (promoted by emotional arousal and interactional synchrony) can promote psychophysiological coherence and, together with LF-PEMF, induce neuronal coherence in different organisms for shared intentionality. The article also showed four factors' domains that contribute to shared intentionality magnitude.

The main purpose of the current research was to provide empirical evidence of shared intentionality during the collaborative performance of related individuals. The data showed a significant outcome; therefore, the Null Hypothesis of shared intentionality absence among the participants should be rejected. At this research stage on shared intentionality, we cannot provide a more sophisticated statistical analysis unless factors of shared intentionality are revealed and controlled. Further, more specified research needs to explore different aspects of the mother-newborn communication model, providing a measurement of post hoc statistical power. We believe that the research outcome contributes to the hypothesis that from the beginning of cognition, shared intentionality allows the nervous system to distinguish particular sensory stimuli from chaos, indwelling with intimately related individuals. The empirical evidence supported the development of bioengineering systems that promote shared intentionality.

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Author Contributions

Igor Val Danilov formulated the hypothesis and wrote the first draft of the manuscript. Igor Val Danilov and Sandra Mihailova improved the text over several iterations.

Competing Interests

The authors have declared that no competing interests exist.

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