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The Origin of Social Skills: Manipulating Shared Intentionality in Bioengineering Systems for Empathy Training

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Abstract

This pilot study (*N* = 28) aims to develop universal computer-aided empathy training. The experiment tests a research design of manipulating behavior in subjects toward non-affective cues in a bioengineering system. The study implements the Mother-Fetus Neurocognitive Model to involve subjects in subliminal cognitive collaboration with confederates, which enables subjects to associate the meaning of empathy with the picture only seen by confederates. The outcome shows the feasibility of the chosen research design with the efficiency of the 7-minute training: 50% of subjects confidentially attribute an empathic attitude to the neutral stimuli, and the probability of such an outcome, in a case if achieved by chance, is only $p = 0.004$. Since subliminal collaboration in adults benefits from the innate quality of shared intentionality, the paper also discusses the genesis of basic emotions and social skills through neuronal coordinated activity in the mother-child dyad beginning from the pregnancy period.

Keywords

Empathy; shared intentionality; social skills learning; psychotherapy

1. Introduction

The pilot study is part of ongoing translational research that aims to develop practical computer-aided applications for different social needs based on evolving knowledge about neurophysiological mechanisms of shared intentionality. Specifically, the current study explores the possibility of manipulating shared intentionality in a group of adults by involving them in the bioengineering system, which can increase empathy in subjects toward neutral stimuli. From now on, we will use the term bioengineering system in its general meaning, which is the application of engineering principles to the design of technology aimed at solving biological problems (see subsection 2.2 Methodological components).

1.1 The State of the Art

The meta-analysis of 18 studies of psychotherapeutic empathy training with a total of 1,018 participants explored whether empathy training is productive [1]. Nowadays, the psychotherapeutic approach encompasses experiential training (games and role-play), didactic (lecture-based), skills training (lectures, demonstrations, and practice), and a mix of the above-noted methods [1]. Despite the positive results, several issues must be addressed to translate these psychotherapeutic methods to create universal empathy training. Firstly, the metaregression found no significant evidence that the number of training hours was associated with effect size [1]. For example, Butters (2010) argued that as little as 1 hr may be effective [1, 2]. Other studies have suggested that between 1 and 3 days of training is effective for physicians [1, 3, 4]. So, there is uncertainty about the number of training hours required. Then, much still needs to be clarified about the effects of empathy training; one of the critical ones is whether empathy training increases empathy in trainees other than university students and health professionals [1]. Studies with adults of other occupancies (other than health professionals) and children and adolescents have not shown the effectiveness of empathy training. Another essential issue in the training programs is the stimulation of the subjects. The literature review showed an association between compensation (monetary and academic credit for a university course) and higher effect sizes [1]. This finding raises several questions. Does empathy training only make sense with some compensation? If so, it doubts the sense of psychotherapeutic empathy training because any compensation contradicts voluntary engagement in caring for other people and having a desire to help them (prosocial behavior is one of the core features of empathy [1]). Finally, this finding also challenges psychotherapeutic training's generalizability because motivation depends on individual particularities. The above-noted issues (the uncertainty in the number of training hours, the training efficiency in only a narrow specific audience, and subjects' stimulation) highlight narrow-focus tuning of the psychotherapeutic approach to empathy training, which may only achieve efficiency in specific patients under certain conditions.

1.2 The Problem of Empathy Appearance

The scientific community has not yet consolidated a precise definition of empathy, considering this broad term includes cognitive, affective, somatic, and spiritual empathy [5-7]. However, a literature review of 52 articles highlighted a developing consensus among neuroscientists, psychologists, medical scientists, nursing scientists, philosophers, and others that empathy involves understanding, feeling, sharing, and self-other differentiation [8]. According to the received view, empathy motivates prosocial behavior [9, 10], while a lack of empathy leads to antisocial behavior [11]. Prosocial behavior refers to people voluntarily engaging in activities that benefit others. Antisocial behavior refers to a cluster of problematic, disruptive, aggressive, and rule-breaking behaviors.

Although the origin and development of empathy are still a matter of ongoing research, its onset is thought to occur early in life, as soon as organisms begin to recognize social reality. Numerous research studies reported that newborns manifest a reaction to the crying of another newborn [12-15]. Newborns responded more strongly to another newborn's cry than to various controlled stimuli, including silence, white noises, synthetic cry sounds, non-human cry sounds, and their cry [12-15]. This quality was also observed in older children. Geangu et al. (2010) showed that during the presentation of a pain cry sound, 1- and 3-month-old infants also manifested increased vocal and facial expressions of distress [16]. The data suggest that infant distress reactions to another infant's cry are not simply a response to the aversive noise of the cry; instead, they may be an early precursor to empathic responding [17]. However, evidence also suggests that children may not imitate others purposely until their second year (after the ninth month of cognitive revolution [18]) and that imitation of different kinds of behavior emerges at different ages [19]. In other words, there is no evidence that newborns imitate others independently and/or can do so intentionally. Despite the lack of understanding of how newborns imitate others, growing evidence shows that this repetition mechanism contributes to the development of cognition and emotions and, therefore, can facilitate evolving empathy.

Given the above-noted arguments, empathy likely requires three distinct skills (following the above definition [8]): the ability to share the other person's feelings, the cognitive ability to intuit what another person is feeling, and a "socially beneficial" intention to respond compassionately to that person's distress [20, 21]. These skills require a categorized reality and intentions towards social facts from the young organisms. On one side, newborns show empathic behavior. On the other side, this behavior requires categorized reality and intentionality, i.e., a cognizing agency, that does not correspond to our knowledge about children's abilities in this stage of development (the simple reflexes substage of the sensorimotor stage of development) when, according to Piaget, organisms manifest goal-directed behavior in simple reflexes only [22].

In solving this dichotomy, scholars from a variety of disciplines — neuroscience, biology, social psychology, sociology, and life-span psychology — have convinced that primitive emotional contagion is of critical importance in understanding empathy evolution [23, 24].

1.3 The Problem of Emotional Contagion

The literature defines primitive emotional contagion as the tendency to automatically mimic and synchronize expressions, vocalizations, postures, and movements with those of another person and, consequently, to converge emotionally [24]. It is already widely argued that primitive emotional contagion is a building block of social interaction, assisting in capturing the mental states of others and cognition [24]. According to Keromnes and colleagues, the subject learns behaviors through imitation and emotional contagion and cannot be dissociated from others during the first months of life [23]. Evidence shows that emotional contagion operates automatically [25] from birth [18]. However, the neurophysiological mechanism of this emotional exchange is also unclear due to the same reason as empathy. The ability of emotional contagion does not correspond to our knowledge about children's behavior at this stage of cognitive development. At this stage, organisms only manifest goal-directed behavior in simple reflexes [22]. An appearance of emotional contagion already requires categorized reality and intentionality, i.e., a cognizing agency. After Piaget, we know that organisms with simple reflexes cannot manifest intentional actions independently [22].

This discrepancy between experimental data on children's achievement (obtained through research) and our knowledge about their abilities at this stage of development (obtained from decades of observation and hundreds of years of parental experience) highlights the problem of cognition beginning [26].

1.4 The Problem of Cognition Beginning

According to the received view, cognition arises in young organisms through the interaction of perceptual and motor processes in an ecological context [27, 28] due to the innate bond of the child with the mother. Already, fetuses demonstrate the first steps of cognitive development [29-34], always indwelling with the mother and her social reality, obeying her circadian rhythms and social routine in the developmental period when even awareness is questioned [26, 35, 36]. After Vygotskiy, we know that cognition begins at the onset of life due to unaware knowledge assimilation through interaction with caregivers. In cognitive sciences, the notion of shared intentionality describes mechanisms of unaware knowledge assimilation in young children [18, 26, 35-39].

The problems in understanding the beginning of cognition, e.g., the binding problem [40] and the problem of morphogenesis [35], raise research interest in exploring what an intrinsic quality of biological systems can provide a template for building an adequate nervous system structure in an embryo carrying out such a brain activity that would be both necessary and sufficient for relevant biological sentience in the specific environment [36].

1.5 Shared Intentionality for Cognition and Empathy

Recent inter-brain neuroscience studies showed increasing temporal-coordinated neuronal activity in pairs of subjects involved in collaborated mental processing compared to the same task that they solved alone [39, 41-45]. The evidence supports that nonlocal neuronal coupling is the central point of the neurophysiological hypothesis of shared intentionality since, in physics, particles with the same physical properties react similarly to the electromagnetic field of the same features, independent of the distance between these particles [36, 46]. Waves propagate through tissues depending on their frequency, intensity, and the medium's resistance; low-frequency waves can propagate in tissues at a long distance. For example, in the case of the mother-embryo ecological system, low-frequency oscillations of the mother's heartbeats may directly impact neurons of the embryonic nervous system in a similar way to how they influence her neural circuits, providing through this non-local neuronal coupling a template for the correct cellular structure development and computation training of the embryo's nervous system, which leads to the beginning of cognition of the young organism [36, 46]. Consequently, empathy may also appear in the prenatal period due to social learning with the mother. From this perspective, shared intentionality is the primary driver of cognition and empathy development at the onset of life [36, 46].

1.6 Shared Intentionality in Adults

After Darwin, we know that any quality manifests itself during the lifespan if it emerges at birth; shared intentionality is an innate ability that remains the human ability during the lifespan. From these perspectives, knowledge about adult empathy development is also growing through research on shared intentionality.

Psychophysiological studies reported an unaware coordinated behavior in adults due to shared intentionality [47-51]. Other research even modulated shared intentionality in adults by emulating the features of the Mother-Fetus Neurocognitive Model [50, 52-55]. They showed that the interactional synchrony of sensorimotor processes in ongoing interpersonal dynamics (where organisms' coordination is cyclically enhanced under ever-growing emotional arousal) in individuals, indwelling in social entrainment, increased individual performance [50, 52-55]. In the primary groups, the confident opinion of several members regarding the quiz item could implicitly modulate the attitude of other members without a particular view (subjects) to this item, forming their choice [50, 52-55]. Under conditions of the mother-fetus neurocognitive model, the unaware conformity of subjects with knower-participants (confederates) emerged during the problem-solving test without interaction via sensory cues between them [50, 52-55]. The quantitative research ($N = 405$, $M = 20$ years) revealed significant evidence of shared intentionality in adults (p-value < 0.001) [55]. The research study defined the environmental features that enabled subjects to exhibit unaware conformity with confederates' attitudes, increasing the quiz performance of the formers by up to 20% [55]. The current study repeats this design to show the association between altered opinions toward empathic symbols and increased empathy in subjects.

1.7 The Aim

The above-noted research [35, 36, 46] supposed that cognition begins during pregnancy due to the mother's and fetus's subliminal collaboration. The features of this bio-system constitute the Mother-Fetus Neurocognitive model (see subsections 1.4 and 1.5). Because the origin of empathy is thought to rely upon natural neurophysiological processes (which are likely universal) that drive children's cognitive development, at least at the beginning, computer-assisted technologies for empathy training can complement the psychotherapeutic methods, making them universal if they employ these innate subliminal processes of trainees, strongly respecting their privacy and intentions. Notably, research showed that subliminal operations during learning of adults increased cognitive performance: unconscious remembering increased recall efficiency over time [56] and yielded greater confidence in that thought [57].

The current study aims to examine a research design of manipulating behavior in subjects toward non-affective cues in a bioengineering system. We test whether this goal-directed behavior of subjects becomes prosocial toward neutral stimuli due to shared intentionality with confederates who have seen them and whether subjects associate a seen neutral symbol with an empathic picture that was seen only by confederates. Because prosocial behavior is associated with empathy [9, 10] and shared intentionality underlies group conformity toward shared stimuli [55], we believe that manipulating subliminal processes of shared intentionality in a bioengineering system can enable empathy growth in subjects to these neutral stimuli.

2. Materials and Methods

The pilot study (*N* = 28: subjects [*n* = 10, *m* = 25 years] and confederates [*n* = 18, *m* = 21 years]) examines the possibility of altering empathy in subjects toward neutral stimuli in a bioengineering system involving them in subliminal cognitive collaboration with confederates and associating the meaning of empathy in subjects with the picture only seen by confederates. The study repeats the method of modulating shared intentionality in a group used in the previous research [52-55]. These studies applied the two-component stimuli: (i) a single harmonic oscillator to enhance interpersonal dynamics in pairs and (ii) unintelligible test items to induce shared intentionality in subjects [52-55].

The current experiment attempts to associate the meaning of "empathy" (by only presenting the word "empathy" to subjects) with an empathic object on a neutral background, which we are only presenting to confederates. In other words, we associate the meaning of empathy in subjects with the unseen specific picture; significantly, subjects can only see the word "empathy," whereas confederates – only see the picture. Then, in the second phase, we ask subjects to choose the empathic picture from the two pictures with different neutral backgrounds (one of them from the first phase) and the same empathic objects placed on both of them. We also tested the subjects' confidence in their choice by posing this question two times (at the beginning of the survey and at the end). We expect that subjects can associate the seen word with the unseen picture. That is, the subjects can "recall" the never-seen picture. The current study repeats the previous research design [52-55], including only the third component – neutral stimuli between unintelligible test items, and providing the "recall" test at the end.

2.1 Procedure

Baseline: we tasted the background recognition without a subliminal intervention. Before the experiment, we tested these two different backgrounds for one empathic stimulus (kitten) in the baseline group of students (*n* = 14, *m* = 25 years). The research question was whether subjects could recognize the other neutral color of the background of the stimulus in a recall task. The neutral color was a monotone, non-affective color, one of the shades of yellow. We showed subjects the kitten on the beige-pink (BP) background and, a few minutes later, asked them to choose what they preferred between two options: the kitten on the beige-pink (BP) background and the kitten on the beige-yellow (BY) backgrounds. The test with 14 subjects showed no significant difference in the preference of beige-pink (BP) backgrounds, with only 43% of participants choosing the BP background.

Therefore, these two backgrounds in the experiment have been chosen as the neutral, non-affective stimulus since these colors are not distinguishable in recalling in the sense of the affective impact. Because the backgrounds are indistinguishable, we added geometric shapes (triangles and squares, which are also non-affective cues) to differentiate them.

We observe the subjects' performance in two phases of the experiment. In the first phase, we present them with 20 unfamiliar items; between the items, we show stimuli for all participants simultaneously 20 times: to subjects the word "empathy" and to confederates an empathic picture (a pretty kitten on the neutral (beige-pink) background, Figure 1).

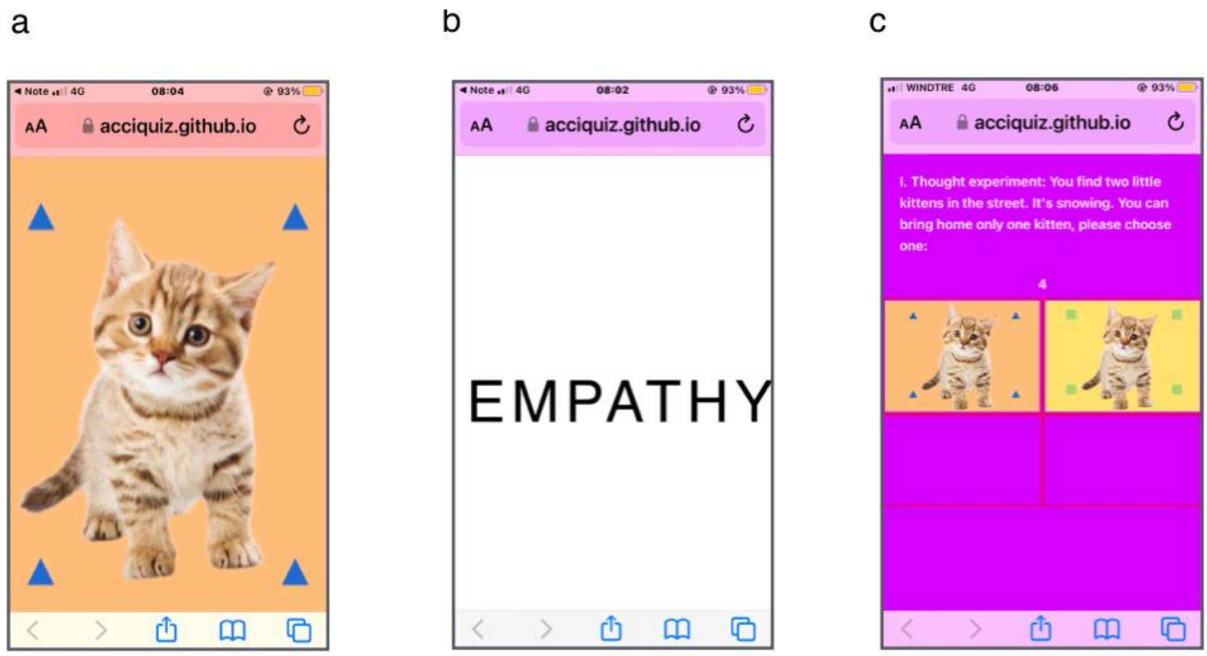

Figure 1 Stimuli for subliminal training: (a) to confederates – a pretty kitten on the beige-pink BP background, (b) to subjects – the word "Empathy." (c) The forced choice "recall": subjects need to choose the kitten on the two backgrounds, the BP background and the beige-yellow (BY) background.

Immediately after the first phase, we proceed with the "recall" phase, where we ask subjects to choose one picture from two options: (a) a pretty kitten on the beige-pink (BP) background and (b) the same kitten but on the beige-yellow (BY) background. We repeat this question in a minute.

Ethical approval for this study was obtained from RTU Liepaja Academy (Approval number 1/2024).

2.2 Methodological Components

1. Assessing objective. Altered empathy in subjects is evidenced by increases in performance above chance, random choice value due to the Bernoulli equation (1), shaped by subjects' answers in the second phase of the "recall" test.

$$P(k) = C^k p^k q^{n-k} \tag{1}$$

The equation shows a probability of subjects' outcome considering them as independent trials, where: *C* – number of combinations *n* by *k*; *p* – the probability of each result of 8 possible; *n* – some independent trials (number of subjects), the likelihood of each is *p* ($0 < p < 1$); *k* - events, how many tasks the subject answers correctly; $q = 1 - p$.

2. Participants (N = 28) are undergraduate students: subjects (n = 10, m = 25 years) and confederates (n = 18, m = 21 years). All participants receive three-component stimuli (see point 3). We attribute them to the primary group in social entrainment. We emulate the mother-fetus neurocognitive (MFN) model by involving them in a bioengineering system. This MFN model should induce neuronal coherence between subjects and confederates when subjects solve unintelligible tasks.

3. Stimuli. The three-component stimuli encourage neurophysiological coherence. The first component is unintelligible test items. The 20 unintelligible items force participants to muster all their properties (explicit and implicit ones). The unintelligible items are meaningless symbols, similar to subjects and confederates (see Figure 2). This condition stimulates shared intentionality in participants since it does not give them another possibility to answer items correctly; the subjects need to choose the correct options, what they do not know, and about what they do not receive any sensory clues.

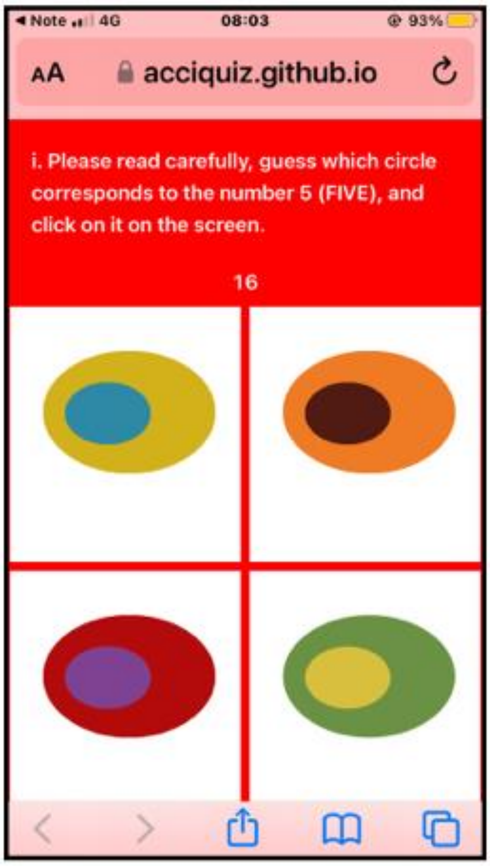

Figure 2 The unintelligible items encourage a shared cognitive process.

The second component of stimuli is the low-frequency pulsed electromagnetic field (LF-PEMF with wavelengths of 700 and 400 nm) [52-55]. The display emits alternately flashing color lights at 700 and 400 nm with a color change frequency of 1.3 Hz.

The third stimuli component is a simultaneous 6-second presentation of the word "empathy" to subjects and a picture of a pretty kitten on a neutral (beige-pink) background to confederates (see Figure 1). We asked this question two times (at the beginning of the survey and the end) to test subjects' confidence in their choice.

These three intersected processes provided neurophysiological coherence in subjects to emulate the communication model. As we supposed, the interpersonal dynamics and long-term corticospinal excitability would provide cell coupling at the neuronal level [52-55].

4. Data collection process. The value is derived in the second phase of the experiment from the difference between the number of subjects' responses of choosing the picture seen before by confederates (the kitten on the beige-pink background) and a chance (random choice value). The

subjects can not improve performance independently since they have not seen the stimulus before; the pretty kitten on the beige-pink background has been seen before only by confederates.

5. Bioengineering system. We create a bioengineering system to induce shared intentionality in groups by emulating the MFN model properties in participants while solving unintelligible multiple-choice puzzles. The bioengineering system stimulates interpersonal dynamics in the participants and facilitates their neuronal coherence by inducing long-term corticospinal excitability. It employs human-computer interaction that stimulates interpersonal dynamics by unintelligible tasks, and low-frequency pulsed electromagnetic fields (LF-PEMF). It consists of two instrumental components: a smartphone and original software in a server. The smartphone is an interface that presents test puzzles and provides data input. At the same time, the smartphone emits alternately flashing color lights at 700 and 400 nm with a color change frequency of 1.3 Hz. The server processes a signal from the input to the output.

3. Results

We consider the only answer combination beige-pink/beige-pink BP/BP as the correct aware answer from 8 possible (–/BP, BP/–, BY/BY, BY/BP, BP/BY, –/BY, and BY/–). The probability of this outcome of one subject is $P = 0.125$. Five subjects out of ten responded correctly. Due to the Bernoulli Equation 1, the likelihood of 5 such answers in 10 subjects is $P = 0.004$, which is a significant result (see Table 1).

Table 1 The results of 10 subjects after the 7-minute subliminal training.

Subject (Year/Name)	Result of 2 questions	Probability
2003K	-/BP	
2004V	BY/BP	
2003L	BY/BY	
2004S	BP/BP	$P = 0.125$
2004-	BP/BP	$P = 0.125$
1997E	BP/BP	$P = 0.125$
1982S	BY/BY	
1991E	BP/BP	$P = 0.125$
2003A	-/BY	
1991I	BP/BP	$P = 0.125$
Total	5 BP/BP	$P = 0.004$

4. Discussion

The novelty of the current study is that it is the first to experimentally test the possibility of subliminal training of empathy in adults. The significance of the study stems from the essential impact of empathy on the development of society, which is widely debated due to its political, economic, and cultural implications. The study contributes to developing a new empathy teaching strategy based on subliminal processes by modulating shared intentionality in a group. Suppose further follow-up studies with a larger sample size demonstrate the efficiency of this subliminal training of empathy. In that case, it will help to develop computer-aided methods for universal socio-emotional learning programs aimed at improving critical social skills in different applications, from treating Post-traumatic stress disorder to correcting antisocial behavior due to environmental factors.

The above perspectives require further research on the nature of shared neural representations beginning from pregnancy. Research on shared neural representations in adults [39, 41-45, 58], in mothers and fetuses [33, 34], and studies on the origins of empathy [59] have been going on for several decades. Recent advances in neuroscience [39, 42-45] and psychophysiological research [47-55] expanded the use of the term Shared intentionality to include consideration of the interaction between the embryo and the mother [35, 36, 46, 60]. The neurophysiological hypothesis of shared intentionality explains cognition at the different levels of interaction between the mother and child, from interpersonal dynamics to neuronal coupling [35, 36, 46, 60]. It shows how the embryo can provide a brain activity that would be both necessary and sufficient for relevant biological sentience in the specific environment [35, 36, 46, 60]. The shared intentionality approach to understanding the evolvement of an adequate nervous system structure in the embryo due to the mother's template yields a range of research perspectives, one of which is the hypothesis of the origin of emotions.

4.1 Limitation: The Identifiability Problem

Using psychometrical instruments, one cannot set up training and measure all the state variables because explicit data about cognitive processes (behavioral data including exhibited decisions and non-physiological manifestations, e.g., eye movements, verbal protocols, etc) only inform us about some aspects of implicit mental activity. If only a subset of the state variables can be controlled, they do not provide sufficient conditions to identify the underlying cognitive subprocesses unequivocally. Anderson called this the identifiability problem, highlighting that in psychometrical measurements, an infinite number of mechanisms compute the same input-output function [61]. When only a subset of the state variables can be measured, then it is possible that some of the system characteristics cannot affect the measured state variables or that they do so in combinations that do not specify the characteristics' outcomes separately. Such characteristics are unidentifiable and inestimable. Therefore, although empathy training can consider many state variables (i.e., essential subjects' traits, including their backgrounds) to tune the training course, the outcome of any empathy training course (provided and/or analyzed only through behavioral data) has some level of uncertainty.

4.2 Limitation: A Dynamic Ecological System

The current study shows that subjects confidently attribute an empathic attitude to neutral stimuli. Other research has already demonstrated that subliminal operations during learning increased recall efficiency over time [56] and yielded greater confidence in that decision [57]. However, the long-term effect of subliminal training should be the scope of further research. This research goal is also intriguing because personality is a dynamic subsystem of an ecological system that also evolves. The features of the evolving environmental system continuously impact personality evolvement, changing individual traits over time. Because trainees' personalities continue to evolve in their dynamic ecological system after training, another challenge for empathy training efficiency is a comprehensive analysis of environmental system dynamics and how these dynamics impact the long-term effect of subliminal training.

4.3 Limitation: A Need for an RCT Design

Because establishing casualty is the objective of any research, a randomized controlled trial (RCT) design has been designated as a type of scientific experiment to reduce bias and provide a rigorous tool to examine cause-effect relationships between an intervention and outcome [62]. This research design balances participant characteristics between the groups (with and without intervention) [62]. Further research on subliminal empathy training should apply RCT in research design to achieve data robustness and method validity.

4.4 Limitation: Small Sample Size

The current pilot study has not calculated a sample size because this experiment aims to check the feasibility of the chosen research design. Further long-term research should calculate the sample size relevant to the task. Because empathy training is a general issue, there is no target group and no eligibility criteria: any participant is equally welcome to be selected in the study. Therefore, the study's sample size on subliminal empathy training is not limited by constraints of Ethical issues or logistics and time restrictions. We would suggest an RCT research design (see above) that examines the effect of an intervention as the difference between two groups (with and without intervention). Given the above arguments, the effect size cannot be determined to calculate an appropriate sample size. For such a case, Cohen recommends using small, medium, and large effect sizes instead of specific values (i.e., standardized or unit-free effect sizes) [63, 64]. Since the mean difference between the two groups is of interest, and if an independent sample t-test would be used, the standardized effect size would be calculated as a ratio (division) of the difference between two means and the standard deviation of responses [64]. The sample size would be based on a range of standardized effect sizes and powers: d = 0.2 (small), 0.5 (medium), or 0.8 (large) [63, 64]. Because, in our case, the effect size obtained in the current pilot study is estimated to be medium, thus according to Cohen, the total sample size required to reach a power of 80% is 128 dyads in two groups: 50% with and 50% without intervention, with 64 confederates + 64 subjects in each group [63, 64] (G*Power Statistical Power Analyses for Mac and Windows version 17 March 2020 Release 3.1.9.7 was used) [65, 66].

5. Conclusions

The study examined the possibility of manipulating behavior in subjects toward non-affective cues in a bioengineering system involving them in subliminal cognitive collaboration with confederates and associating the meaning of empathy in subjects with the picture only seen by confederates. The experiment showed significant efficiency of the 7-minute training – 50% of subjects attributed an empathic attitude to the neutral stimuli with solid confidence. If achieved by chance, the probability of such an outcome is only P = 0.004. Based on this knowledge, further translational research can develop universal socio-emotional learning programs that could employ subliminal neurophysiological processes (innate and universal), at least to monitor intervention efficiency and avoid issues related to trainees' particularities, differences in motivational intensity and sensitivity to the psychotherapeutic intervention. This progress would improve empathy training programs for different applications, from treating Post-traumatic stress disorder to correcting antisocial behavior caused by environmental factors.

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Author Contributions

Sandra Mihailova (SM) and Igor Val Danilov (IVal) created the research design of the experiment and conducted it together. IVal formulated the hypothesis and wrote the first draft of the manuscript. SM and IVal improved the text over several iterations.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Teding van Berkhout E, Malouff JM. The efficacy of empathy training: A meta-analysis of randomized controlled trials. J Couns Psychol. 2016; 63: 32.
2. Butters RP. A meta-analysis of empathy training programs for client populations. Salt Lake City, UT: The University of Utah; 2010; UMI Number 3398227.
3. Berkhof M, van Rijssen HJ, Schellart AJ, Anema JR, van der Beek AJ. Effective training strategies for teaching communication skills to physicians: An overview of systematic reviews. Patient Educ Couns. 2011; 84: 152-162.
4. Gresham FM, Sugai G, Horner RH. Interpreting outcomes of social skills training for students with high-incidence disabilities. Except Child. 2001; 67: 331-344.
5. Hall JA, Schwartz R. Empathy present and future. J Soc Psychol. 2019; 159: 225-243.
6. Cuff BM, Brown SJ, Taylor L, Howat DJ. Empathy: A review of the concept. Emot Rev. 2016; 8: 144-153.
7. Bellet PS, Maloney MJ. The importance of empathy as an interviewing skill in medicine. JAMA. 1991; 266: 1831-1832.
8. Eklund JH, Meranius MS. Toward a consensus on the nature of empathy: A review of reviews. Patient Educ Couns. 2021; 104: 300-307.
9. Telle NT, Pfister HR. Not only the miserable receive help: Empathy promotes prosocial behaviour toward the happy. Curr Psychol. 2012; 31: 393-413.
10. Eisenberg N, Miller PA. The relation of empathy to prosocial and related behaviors. Psychol Bull. 1987; 101: 91.
11. Björkqvist K, Österman K, Kaukiainen A. Social intelligence – empathy = aggression? Aggress Violent Behav. 2000; 5: 191-200.
12. Dondi M, Simion F, Caltran G. Can newborns discriminate between their own cry and the cry of another newborn infant? Dev Psychol. 1999; 35: 418-426.
13. Martin GB, Clark RD. Distress crying in neonates: Species and peer specificity. Dev Psychol. 1982; 18: 3-9.

14. Sagi A, Hoffman ML. Empathic distress in the newborn. Dev Psychol. 1976; 12: 175-176.
15. Simner ML. Newborn's response to the cry of another infant. Dev Psychol. 1971; 5: 136-150.
16. Geangu E, Benga O, Stahl D, Striano T. Contagious crying beyond the first days of life. Infant Behav Dev. 2010; 33: 279-288.
17. McDonald NM, Messinger DS. The development of empathy: How, when, and why. Moral behavior and free will: A neurobiological and philosophical approach. Coral Gables, FL: University of Miami; 2011. Available from: http://www.psy.miami.edu/faculty/dmessinger/fp/vita.htm.
18. Tomasello M. Becoming human: A theory of ontogeny. London: Harvard University Press; 2019.
19. Jones SS. The development of imitation in infancy. Philos Trans R Soc B. 2009; 364: 2325-2335.
20. Decety J, Ickes W. The social neuroscience of empathy. Cambridge, MA: MIT Press; 2011.
21. Decety J, Jackson PL. The functional architecture of human empathy. Behav Cogn Neurosci Rev. 2004; 3: 71-100.
22. Piaget J, Cook M. The origins of intelligence in children. New York: International Universities Press; 1952.
23. Keromnes G, Chokron S, Celume MP, Berthoz A, Botbol M, Canitano R, et al. Exploring self-consciousness from self-and other-image recognition in the mirror: Concepts and evaluation. Front Psychol. 2019; 10: 719.
24. Hatfield E, Cacioppo JT, Rapson RL. Emotional contagion. Curr Dir Psychol Sci. 1993; 2: 96-100.
25. Heyes CM. Empathy is not in our genes. Neurosci Biobehav Rev. 2018; 95: 499-507.
26. Val Danilov I, Mihailova S. A new perspective on assessing cognition in children through estimating shared intentionality. J Intell. 2022; 10: 21.
27. Lillard-Polk P. Montessori: A modern approach. Chapter 2: The montessori philosophy. New York: Schocken Books; 1972.
28. Delafield-Butt JT, Trevarthen C. The ontogenesis of narrative: From moving to meaning. Front Psychol. 2015; 6: 98961.
29. Castiello U, Becchio C, Zoia S, Nelini C, Sartori L, Blason L, et al. Wired to be social: The ontogeny of human interaction. PloS One. 2010; 5: e13199.
30. Kisilevsky BS. Fetal auditory processing: Implications for language development? In: Fetal Development: Research on brain and behavior, environmental influences, and emerging technologies. Cham: Springer; 2016. pp. 133-152.
31. Lee GY, Kisilevsky BS. Fetuses respond to father's voice but prefer mother's voice after birth. Dev Psychobiol. 2014; 56: 1-11.
32. Lecanuet JP, Granier-Deferre C, Jacquet AY, Capponi I, Ledru L. Prenatal discrimination of a male and a female voice uttering the same sentence. Early Dev Parenting. 1993; 2: 217-228.
33. Hepper P. Behavior during the prenatal period: Adaptive for development and survival. Child Dev Perspect. 2015; 9: 38-43.
34. Jardri R, Houfflin-Debarge V, Delion P, Pruvo JP, Thomas P, Pins D. Assessing fetal response to maternal speech using a noninvasive functional brain imaging technique. Int J Dev Neurosci. 2012; 30: 159-161.
35. Val Danilov I. Low-frequency oscillations for nonlocal neuronal coupling in shared intentionality before and after birth: Toward the origin of perception. OBM Neurobiol. 2023; 7: 192.
36. Val Danilov I. Theoretical grounds of shared intentionality for neuroscience in developing bioengineering systems. OBM Neurobiol. 2023; 7: 156.

37. Vincini S. Taking the mystery away from shared intentionality: The straightforward view and its empirical implications. Front Psychol. 2023; 14: 1068404.
38. Vincini S, Gallagher S. Developmental phenomenology: Examples from social cognition. Cont Philos Rev. 2021; 54: 183-199.
39. Fishburn FA, Murty VP, Hlutkowsky CO, MacGillivray CE, Bemis LM, Murphy ME, et al. Putting our heads together: Interpersonal neural synchronization as a biological mechanism for shared intentionality. Soc Cogn Affect Neurosci. 2018; 13: 841-849.
40. Treisman A. Solutions to the binding problem: Progress through controversy and convergence. Neuron. 1999; 24: 105-125.
41. Astolfi L, Toppi J, De Vico Fallani F, Vecchiato G, Salinari S, Mattia D, et al. Neuroelectrical hyperscanning measures simultaneous brain activity in humans. Brain Topogr. 2010; 23: 243-256.
42. Szymanski C, Pesquita A, Brennan AA, Perdikis D, Enns JT, Brick TR, et al. Teams on the same wavelength perform better: Inter-brain phase synchronization constitutes a neural substrate for social facilitation. Neuroimage. 2017; 15: 425-436.
43. Hu Y, Pan Y, Shi X, Cai Q, Li X, Cheng X. Inter-brain synchrony and cooperation context in interactive decision making. Biol Psychol. 2018; 133: 54-62.
44. Painter DR, Kim JJ, Renton AI, Mattingley JB. Joint control of visually guided actions involves concordant increases in behavioural and neural coupling. Commun Biol. 2021; 4: 816.
45. Liu J, Zhang R, Xie E, Lin Y, Chen D, Liu Y, et al. Shared intentionality modulates interpersonal neural synchronization at the establishment of communication system. Commun Biol. 2023; 6: 832.
46. Val Danilov I. Shared intentionality modulation at the cell level: Low-frequency oscillations for temporal coordination in bioengineering systems. OBM Neurobiol. 2023; 7: 185.
47. Atmaca S, Sebanz N, Prinz W, Knoblich G. Action co-representation: The joint SNARC effect. Soc Neurosci. 2008; 3: 410-420.
48. Shteynberg G, Galinsky AD. Implicit coordination: Sharing goals with similar others intensifies goal pursuit. J Exp Soc Psychol. 2011; 47: 1291-1294.
49. McClung JS, Placì S, Bangerter A, Clément F, Bshary R. The language of cooperation: Shared inten-tionality drives variation in helping as a function of group membership. Proc R Soc B Biol Sci. 2017; 284: 20171682.
50. Val Danilov I, Mihailova S, Perepjolkina V. Unconscious social interaction, coherent intelligence in learning. Proceedings of the 12th annual conference ICERI; 2019 November 11-13; Seville, Spain. Valencia, Spain: IATED Academy.
51. Tang N, Gong S, Zhao M, Gu C, Zhou J, Shen M, et al. Exploring an imagined "we" in human collective hunting: Joint commitment within shared intentionality. In: Proceedings of the annual meeting of the cognitive science society. Oakland, CA: The University of California; 2022.
52. Val Danilov I, Mihailova S, Svajyan A. Computerized assessment of cognitive development in neurotypical and neurodivergent children. OBM Neurobiol. 2022; 6: 18.
53. Danilov IV. A bioengineering system for assessing children's cognitive development by computerized evaluation of shared intentionality. Proceedings of the 2022 International Conference on Computational Science and Computational Intelligence; 2022 December 14; Las Vegas, NV, USA. Piscataway Township: IEEE.

54. Val Danilov I, Svajyan A, Mihailova S. A new computer-aided method for assessing children's cognition in bioengineering systems for diagnosing developmental delay. OBM Neurobiol. 2023; 7: 189.
55. Val Danilov I, Mihailova S. Empirical evidence of shared intentionality: Towards bioengineering systems development. OBM Neurobiol. 2023; 7: 167.
56. Graf P, Mandler G. Activation makes words more accessible, but not necessarily more retrievable. J Verbal Learn Verbal Behav. 1984, 23: 553-568.
57. Hasher L, Goldstein D, Toppino T. Frequency and the conference of referential validity. J Verbal Learn Verbal Behav. 1977; 16: 107-112.
58. Becchio C, Adenzato M, Bara BG. How the brain understands intention: Different neural circuits identify the componential features of motor and prior intentions. Conscious Cogn. 2006; 15: 64-74.
59. De Waal, Frans BM. The antiquity of empathy. Science. 2012; 336: 874-876.
60. Val Danilov I. Shared intentionality before birth: Emulating a model of mother-fetus communication for developing human-machine systems. In: Intelligent Systems and Applications. Cham: Springer; 2024. pp. 56-69.
61. Anderson JR. The adaptive character of thought. New York: Psychology Press; 2013.
62. Hariton E, Locascio JJ. Randomised controlled trials - The gold standard for effectiveness research. BJOG. 2018; 125: 1716.
63. Cohen J. Statistical power analysis for the behavioural sciences. 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.
64. Althubaiti A. Sample size determination: A practical guide for health researchers. J Gen Fam Med. 2022; 24: 72-78.
65. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007; 39: 175-191.
66. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. Behav Res Methods. 2009; 41: 1149-1160.