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Emotions in e-Learning:
The Review Promotes Advanced Curriculum by Studying Social Interaction

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Abstract
This study presents, for the first time, (a) the analysis of the modern literature on the reciprocal impact of emotional arousal and interactional synchrony that creates the synergy of this tandem increasing group productivity; (b) the empirical results of 10 online experiments with 41 dyads. These online experiments in different languages found a 54% increase in group productivity (41% above chance, the p-value < 0.001). The research question of the study is to understand why individuals look for synchrony. A highlight of the article is the hypothesis about the emergence of coherence of emotional arousal and interactional synchrony, the outcome of which enhances group performance. This Model of Coherent Intelligence is supported by laws of Physics and arguments of Social Sciences which are strictly based on experimental data in the modern literature. The study proposes directions for improving e-learning, using Coherent Intelligence.
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Keywords: Arousal, Coherent Intelligence, Interactional synchrony, Social cognition, Social entrainment, Synchronization

Introduction

The impact of new technologies on changes in society encourages the development of e-learning methods. Moreover, the growing field of knowledge and its multicultural environment demand the development an advanced curriculum in order to facilitate education. These challenges require the improvement of social interaction in e-learning. There is growing evidence of the effectiveness of coordinated interaction in mothers and infants through unintentional mirroring: social entrainment (Aschoff, 1963; Grandin et al., 2006), early imitation (Meltzoff & Moore, 1977; Danilov, in press) and interactional synchrony (Condon & Ogston, 1967; Markova et al., 2019). An impact of arousal on a group performance is also well studied (e.g., Hebb, 1955; Miller et al., 2007; Cirelli et al., 2019). It is widely argued that temporal coordination with co-species contributes to cognitive development of individuals and social cognition, appearing in a wide range of research from different approaches that study: inter-brain neural synchronization (e.g., Valencia & Froese; 2020) and interactional synchrony. There are many different terms and definitions of the latter concept which are also presented in the literature. For instance, another version of the term – interpersonal synchrony – defines the phenomenon as the cases when the movements of two or more people overlap in time (Rennung & Göritz, 2016). Another one suggests: 'Behavioural synchrony complements imitation during interindividual interaction by providing a temporal coherence between the interacting partners (Dumas G, et al., 2011, p.2).' According to Mogan et al. (2017), synchrony is the rhythmic matching of actions both in time and in phase with another person. Markova et al. (2019) highlighted the devision of the phenomena between concurrent synchrony (e.g., joint action, mutual gaze, mirroring) and sequential synchrony (e.g., turn-taking, reciprocity, imitation). The importance of stability and universality of the term and its definition for studying of the phenomenon is obvious due to the several arguments, while the analysis of the problem from semantical and hermeneutical approaches is not a focus of the current article. At the same time, it is important to highlight that the term establishes the main research question to study the phenomena. The wide range of terms of this phenomenon can mean both that its

appearance in social reality is more universal and widespread than our knowledge of it and our understanding its contribution to social reality; and/or there are various phenomena of temporal coordination, and not just one that science attempts to describe, meaning only one – we sometimes find what we are able to understand but not what we can find. For instance, Dobbins & Grossmann, 2018 conducted experiments in which participants had to describe objects that rotated ambiguously in depth, i.e., the testees did not see these objects well enough to understand their movement. The subjects described this movement as synchronous although in reality this was not the case. The interpretation of these results can be at least twofold. Our brains are always trying to find synchronicity in the movements of objects, probably because: (a) evolution advantages for survival demand predicting social reality (Prochazkova & Kret, 2017; Adolphs, 2001), therefore our brains extract patterns of information that provide predictions, temporal coordination of movements is more predictable – in this way the brain tries to make it easier for itself; and/or (b) cognitive development and social cognition require individuals to link with relatives (and/or mates) and coordinate with them in order to distribute knowledge (and/or improve collaboration), ensuring ongoing development which is also an evolutionary advantage for survival. Therefore the current study investigates why individuals should be temporally coordinated with others.

This intriguing question can also be applied to learning. Understanding the efficiency of adult learning encounters challenges: (a) to distinguish previous experience on this topic from a new one, the results of experiment should be based on the solving experimental task, and not on recalling something acquired by subjects at the past; and (b) to exclude any association of materials from the research design and experimental environment during experiment that can link the experimental task with participants' memory on other topics, creating new knowledge on the topic of the experiment. Consequently, the efficiency of learning – in particular retention and all possible modalities of social interaction – can be better studied in experiments on initial learning in infants. According to the Model of Hierarchical Complexity (Commons, 2016), in initial stages of development (0-3 Stages refer to the period for infants from birth to about 3 months of age) organisms are not able to maintain communication, because it arises from the exchange of symbols, while abstract thinking appears at later stages.

Therefore in specific, the research question is twofold: First, the article observes the literature on newborns and 3-month-old infants for (i) discussing the factors of interactional synchrony; (ii) detecting or refuting the coherence of arousal and interactional synchrony, and their impact on improving group performance; (iii) proposing a hypothesis of the mechanism of the emergence of coherence of emotional arousal and synchronous unintentional movements, that contributes to social cognition. Second, the study conducts online experiment with dyads in order to verify the hypothesis.

Features of interactional synchrony

Condon and Ogston (1967) introduced two terms of temporal coordination. They defined self-synchrony as ‘the body dances in time with speech (Condon and Ogston, 1967, p.225)’, which means ‘a precise correlation between the changes of body motion and the articulated patterns of the speech stream (p. 227)’. The next term they introduced was interactional synchrony which is ‘share patterns of bodily changes in a precise harmony with the mother as she spoke (p. 229)’. That is, ‘the body of the speaker was found to ‘dance’ synchronously with the articulatory segmentation of his speech. Further, the body of the listener was found to ‘dance’ synchronously with the speaker, primarily up to and including word length segments (p. 234).’ This may mean that interactional synchrony does not imply only similarity of movements. According to Kendon (1970) one of the main conditions of interactional synchrony arousal and its function in interaction is that when listener synchronizes with the speaker, this individual demonstrates his ability to anticipate the speaker’s thought. This feedback to the speaker smoothens the running of the conversation (Kendon, 1970). Therefore, the main features of this phenomenon of interactional synchrony introduced by Condon and Ogston (1967) and further studied by other researchers are: (1) the property of subjects: familiar individuals from four-year-olds; (2) the property of the environment: the phenomenon occurs in a conversation during an event, which is a cyclical routine for all participants; (3) the property of social interaction: a purpose and meaning of the collaboration are shared among participants; (4) property of stimuli: social interaction establishes an interpersonal rhythm. The outcome of

interactional synchrony is social dynamics through a common rhythm of social interaction of different modalities.

Features of emotional arousal

Emotional arousal is a tendency to take mental states of others, or to automatically synchronize expressions (Hatfield et al., 1993), it is sharing emotion without self- awareness (Decety & Jackson, 2004). The rapid spread of an emotion from one or a few individuals to others (APA Dictionary of psychology, n.d.). It operates automatically (Heyes, 2018), occurs from birth without understanding social reality (Danilov & Mihailova, in press).

The main features of the emergence of arousal are (1) the property of subjects: familiar individuals; (2) the property of the environment: the phenomenon occurs during social interaction under supranormal stimuli; (3) the property of social interaction: a purpose and meaning of the encounter are shared among participants; (4) property of stimuli: supranormal stimuli are operationalized by supranormal situation, e.g., new environment, new social reality, new tasks and so on.

Method

At the first step, the article investigates the research question by observing the modern literature. The studies were chosen for the review because they show empirical data on (a) group outcome in experiments on: memory retention and interactional synchrony, as well as on facial recognition, word categorization and a phenomenon of reaction to the crying of another newborn in newborns and 3- to 4-month-old infants; (b) interpersonal neural synchronization during teamwork experiments, if their baseline also represents neural dynamics of individuals solving the same task, but alone.

There are several assumptions of choosing articles for the review:

(1) Mother-infant dyads very often pass to the state of interactional synchrony because of supranormal stimuli. Social entrainment provides a timing cue for a biological rhythm. This notion was also applied to humans capacity to become entrained with one another or with an external stimulus (Aschoff, 1963). The social entrainment refers to a coordinated state between two individuals that results when their behavior is coordinated by social zeitgebers (time-giver) during cyclical daily rhythm (Grandin et al., 2006). The infant's social entrainment to the mother helps this organism maintain an adaptive relationship with the environment (Olds & William, 2015). These organisms are in the state of social entrainment from birth, and can pass to interactional synchrony as fast as supranormal environment demands them.

(2) 3- to 4-month-old infants were emotionally excited during the experiments if these experiments were carried out in laboratories, regardless of whether the studies have registered arousal or not. The growing body of literature shows the effect of arousal on behavior and performance. It is widely argued that autonomic arousal affects heart rate, pupil dilation, and galvanic skin response, which are used to detect arousal in subjects (Wang et al., 2018). There is limitation of all these measurement approaches – the baseline of many experiments already contains of increased arousal. Because the measurement of the baseline in many experiments were registered in the laboratory before the test, which was already supranormal stimulus for infants. Therefore some experiments with infants were carried out under "preliminary" emotional arousal of participants, although it is obvious that this does not exclude their results because the arousal in the baseline (before the experiments) should be less than when solving tasks. The important conclusion for the current study is that during the experiments in laboratories, the subjects were under emotional arousal. Many others studies on infant performances did not consider arousal as a research variable while its emergence was also very likely due to supranormal stimuli during the experiments.

(3) The review observes articles about experiments in which dyads stood under supranormal environment – in laboratories with strangers.

Therefore, considering above mentioned assumptions, the current review also included articles in which arousal and interactional synchrony were not recorded, mentioning that they in any case appeared to some extent.

At the second step, the study discusses the results of 10 online experiment conducted with 41 dyads.

Findings

Evidence of facial recognition and word categorization in infants

The growing empirical evidence from studies of the last 50 years presents interesting facts about the achievements of newborns and infants in face recognition. The recent article about social behavior in infants (Danilov, 2020c) observed the 18 experiments of other researchers on facial mimicry and word categorization in infants and highlighted:

(i) Newborn tracked a moving schematic face with a strong preference for the face patterns over the other stimuli (Goren et al., 1975; Johnson et al., 1991);

(ii) Newborns demonstrated preference for their mother's face over a stranger's face (Bushnell et al., 1989; Bushnell et al., 2001; Field et al., 1984; Pascalis et al., 1995);

(iii) Newborns prefer faces from their own-ethnic group (Kelly et al., 2007; Pascalis et al., 1994);

(iv) Preferences of infants depend on their caregivers (Quinn et al., 2002);

(v) 3-month-old infants prefer the natural composition of inner features of faces rather than the same features, but in an unnatural position (Turati et al., 2004);

(vi) Newborns recognize familiar faces even presented partly (Simion et al., 2007);

(vii) Newborns prefer attractive faces (Quinn et al., 2008);

(viii) The 3- to 4-months-old infants prefer attractive faces of cats (Quinn et al., 2008);

(ix) The 6- to 9-months-old infants recognize race even through observing grayscale faces in black-and-white photographs (Anzures et al., 2011);

(x) The 3-months-old infants from cross-race environment did not show Other Race Effect (Bar-Haim et al., 2006; Gaither et al., 2012);

(xi) The 3- to 4-months-old infants already can categorize words – fishes and dinosaurs from different classes – that do not fit into their personal reality (Ferry et al., 2010; Perszyk & Waxman, 2019).

Evidence of newborns reaction to the crying of another newborn

According to Danilov and Mihailova (in press), growing empirical evidence suggests (xii) a newborn's reaction to the crying of another newborn (Dondi et al., 1999; Martin & Clark 1982; Sagi & Hoffman 1976; Simner 1971). They responded more often to another infant's cry than to a variety of controlled stimuli, including white noises, synthetic cry sounds, silence, non-human cry sounds, and their own cry (Dondi et al., 1999; Martin & Clark 1982; Sagi & Hoffman 1976; Simner 1971). Geangu et al. (2010) show that during the presentation of a pain cry sound, 1- and 3-month-old infants manifest increased vocal and facial expressions of distress.

Evidence of infants achievements in learning

The modern literature shows very few studies which explored learning of very young infants. Their review presents another interesting fact (xiii): In the behavior synchrony state of Mother-infant dyads, 3-month-old infants demonstrated both an improved learning and increased short-term memory (Thompson & Trevathan, 2008; Morrongiello et al., 2003).

Evidence of interpersonal neural synchronization during teamwork experiments

The recent review of studies on the association between neural oscillations and functional integration (synchronization) by Valencia and Froese (2020) reveals two interesting facts of interpersonal neural coordination:

(xiv) An anomalous synergy of neural coordination in group collaboration – a greater interpersonal neural coordination in subjects solving a puzzle together, compared individual work on the identical task, but alone (Fishburn et al., 2018) – shows the cooperation of the participants, which cannot be explained by their perceptual interaction.

(xv) The similar effect was revealed between two individuals when singing together, but not when singing individually yet close to each other (this effect was not observed in random pairs) (Osaka et al. 2015).
The Model of Coherent Intelligence (MCI) proposes below a hypothesis on the physical mechanism of such a synergy.

Discussion

These facts were obtained from experiments where (1) the property of subjects: familiar individuals with infant from birth to 4-month-olds; (2) the property of the environment: supranormal stimuli of unusual situation for dyads which could involve them in social entrainment; (3) the property of social interaction: a purpose and meaning of the collaboration were shared among caregivers and infants; (4) property of stimuli: social interaction of different modalities. These factors are very similar to those that establish and stimulate separately both arousal and interactional synchrony, and even in studies where these variables were not taken into account by researchers, it is likely that both arousal and interactional synchrony arose there. Obviously, the participants were in the emotional arousal state due to supranormal situation for them. Interactional synchrony and arousal accompany the everyday life of dyads, because they are already connected through a state of social entrainment from birth, as mentioned above, which promotes easy passing to their co-arousal and temporal coordination in any supranormal environment. This ability is manifested in daily routine when infants mirroring sounds and body movements, the frequency of which is correlated with frequency of their mothers (Markodimitraki and Kalpidou, 2019; Heyes, 2020).
There is another argument in supporting the supposition that interactional synchrony and arousal contribute to outcomes in laboratories, even their appearance was not recorded. Studies of infants behavior in natural environment do not support laboratory results. The very few studies were conducted on infants behavior in a naturally occurring context in their homes. The results of these studies show that in a natural environment newborns do not play an active role in face-to-face communication with the mother in the 1st month, and only from around the beginning or the middle of the 2nd month the mothers started to mark these communicative infant actions (e.g., Lavelli & Fogel, 2002; Kugiumutzakis, 1999; Trevarthen, 1998; Reddy et al., 1997). This means that during experiments, newborns manifested unusual behavior for them in comparison to their own behavior under natural conditions at home.
Therefore supranormal stimuli of experimental performance in laboratories could stimulate interactional synchrony and arousal in dyads. Taking also into account above evidence of the behavior of children in natural environment, this tandem should be taken into account when discussing outcome of the experiments in laboratories. Interesting facts (facts from i to xiii) of infant cognitive enhancement can be explained if they can be revised to account for the likely interactive synchronicity and arousal during experiments in dyads. It is obvious that the above achievements of very young children do not correspond to the stage of their development, given also their lack of communication skills. Young infants do not understand the meaning of social reality on their own in such an extent to successfully classify social phenomena that are abstract and/or absent from their reality. At stage 3 of development organisms are neither able to perceive abstract phenomena nor maintain communication, because abstract thinking appears at later stages.

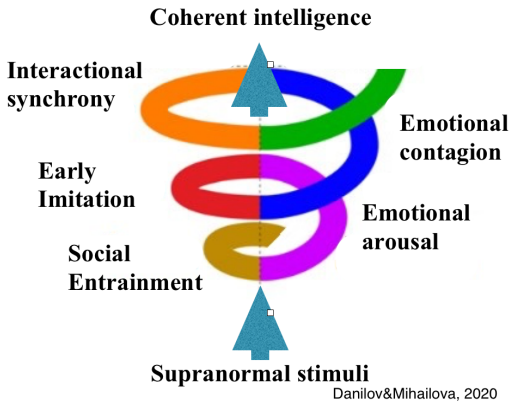
The Model of Coherent Intelligence (MCI)

The above facts and arguments allow us to put forward the hypothesis about the emergence of coherence of emotional arousal and interactional synchrony, the outcome of which enhances group performance. In the laboratory experiments this helps infants solve insoluble tasks for them. The MCI shows that ongoing social dynamics creates a coherent mental process in groups where coordination of movements is cyclically enhanced under ever-growing arousal. A supranormal environmental case – e.g., first hours after birth – stimulates supranormal sensation in dyads. This can push the inherited mechanism of social entrainment of infants to the rhythm of the mother. Both the supranormal sensation and social entrainment may stimulate the common emotional arousal. The latter is increased by the ongoing supranormal sensation and the occurring rhythm of arbitrary movements of the infant. The continuing supranormal sensation and ever-increasing arousal of the infant and the mother along with the rhythm of the infant's unintentional movements stimulate early imitation

and emotional contagion. The problem is how the infant capture and reproduce the kinematic of movements. The MCI proposes that common emotional arousal together with the identical rhythm create coherent mental processes in dyads – Coherent Intelligence (see Picture 1). At Stage 3 of the Model of Hierarchical Complexity (Commons et al., 1982; Commons, 2016) organisms do not maintain bilateral communication. According to Danilov and Mihailova (in press) individuals are able to communicate at this Stage by distinguishing perceptual signals of identical modality by their value (significance). This ability to imply different values to identical perceptual stimuli, can contribute to ostensive cues. This meaningless interaction after all modifies into communication, when individuals imbue perceptual impulses with mutually implied meanings, cascading their signals in response to the history of relations between them.

A coherent mental process (e.g., during cooperation in problem solving or choral singing) emerges when neural circuits of different organisms are associated through connected neurons. That is, this coherence is possible if their neurons can be linked by an entanglement state based on the laws of physics – non-perceptual interaction among individuals. This connection of neurons can associate neural circuits of different organisms, supporting their cooperation in mental process – coherent intelligence (Danilov et al., 2019). Knowledge on consciousness is being developed through the study of the interaction of neurons, which definitely obey laws of physics. The growing empirical data in physics evidently show that quantum entanglement occurs when two particles become linked and behave the same, regardless of the distance between them. Recent research show that living cells can also become entangled (Marletto et al., 2018). Evidence for increased interpersonal neural synchronization due to collaboration in team work experiments (facts xiv and xv) probably supports the hypothesis of coherent intelligence.

Picture 1. The Model of Coherent Intelligence



Results, Conclusions and Recommendations

The above arguments show that one of the possible explanation of the infants achievements in laboratory experiments is a mental collaboration with their mother (caregivers) supported by non-perceptual social interaction – coherent intelligence. This conclusion is also supported by interpretation of evidence from studies on the association between neural oscillations and functional integration (facts xiv and xv). The current study on coherent intelligence in mother-infant dyads presents, for the first time, empirical evidence of coherent intelligence in dyads in 10 online experiments with 41 groups (41 Mothers and 45 children, M=9). These online experiments in different languages found a 54% increase in a group performance (41% increase above chance, the p-value < 0.001). These results support the MCI, which demonstrates the mutual influence of emotional arousal and interactional synchrony, that improves group performance.

Future work

This study shows the flexibility and potential of the phenomenon of Coherent Intelligence in e-learning. It is widely believed that one of the main weaknesses of e-learning is the lack of face-to-face interaction and shortage

of input from trainers, that is, there is no substitute for interacting with, and learning from, a fellow human. The Problem-Based Learning curriculum also requires confident involvement in its process of high-order thinking with deep levels of information processing to achieve success (Danilov, 2020). We believe that the findings of the current article open up a new approach to understanding the impact of social interaction and help create an innovative e-learning curriculum that could incorporate higher-order thinking with deeper levels of information processing to facilitate knowledge acquisition, achieving richer memory structures in students during e-learning. The article also proposes a new approach to study the initial comprehension of social reality among young infants largely occurs within the framework of non-perceptual social interaction with their caregivers, and emotional contagion, that makes a contribution to the formation of social reality.

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