Interpersonal Synchronization
The Biology of Connection

Amie S. Koontz

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Abstract

When people relate to one another, perform activities together, or touch, a connection often forms between them. A common denominator among those who live long, happy, healthy lives is having strong connections with others. As professions and fields of thought, psychology and medicine often approach mental and physical health as separate entities. The treatment modalities in each field reflect this approach, with talk therapy dominating the practice of individual and relationship counseling. Research demonstrates that practices which improve one's biological health, such as yoga, eating well and exercise have a positive impact on mental health as well. We know that biology affects mental health, yet we approach mental health and relationships as though they can only be treated and improved with thought processes, using cognitive and talk therapy, or with medication. This paper suggests that the mental health of individuals, dyads and groups of people might benefit from a non-medicinal, biological approach in addition to, or in some cases in place of, cognitive or medical approaches to mental health. More specifically, this paper seeks to explore the biology of 'connection' and postulate that it might be used to strengthen relationships and the health of those in them, by providing opportunities which promote a combination of interpersonal synchronization and time out of synchrony, actions which foster self and co-regulation. In this paper, I will examine synchronization as it occurs in nature. This review will define interpersonal synchronization (IS) and identify different types of IS. I will explore theories on why and how IS occurs, what role it plays in human development, which factors influence the level of interpersonal synchronization, and how IS affects human interaction. Finally, I will explore potential therapeutic implications of IS including: ways it might be incorporated into therapy, its effect on therapeutic alliance, therapeutic longevity and clinical success, teaching empathy, relationship and family cohesion, treatment of trauma and group functionality and cooperation.

What is Synchronization?

"Unentangled (independent) states are rare exceptions, for whenever systems interact, the interaction creates correlations between them."

-Frank Wilczek, American theoretical physicist, mathematician, Nobel laureate and the Herman Feshbach Professor of Physics at the Massachusetts Institute of Technology

Spontaneous synchronization is a notable natural phenomenon in which a pair or group of oscillating units, which have differing frequencies, spontaneously evolve to oscillate at a common frequency (Gupta, 2018). In 1665, a scientist named Christiaan Huygens made the observation that if two pendulum clocks were hung on the same wall or base, they would eventually synchronize. If one of the pendulums was reset out of sync, within a short period of time, the two clocks would synchronize again. This remarkable occurrence is now known as 'Huygens synchronization' and is thought to lend insight into not just mechanical systems, but also systems within the human body and between organisms. (Ramirez, Olvera, Nijmeijer, & Alvarez, 2016). "That such an effect has kept scientists fascinated for a good 350 years is partly due to the fact that many similar occurrences of synchronization are present in engineering and in nature, like imbalanced rotor motion or the human heartbeat." (Ramirez et al. 2016, p.6).

Self-organization and spontaneous order are terms used in the social and natural sciences to describe chaotic systems that seemingly spontaneously organize. Synchronization is one such type of organization. Spontaneous synchronization can be seen in nearly every realm of life. It occurs in biological, chemical, robotic, physical, and cognitive interactions and can be seen in swarming insects, crickets chirping in unison, groups of sperm, pacemaker cells, fireflies blinking together, power grids finding a common frequency, people applauding or walking next to each other, clusters of neurons and even the circadian rhythms of plants (O'Keeffe, Hong, & Strogatz, 2017; Wolchover, 2019).

Winfree, Kuramoto, and Haken, Kelso and Bunz all came up with mathematical models for spontaneous synchrony and self organizing systems in machines and living beings. I propose that psychology can benefit from examining overlap with mathematical concepts as well as biological ones.

Interpersonal Synchronization

Interpersonal synchronization can be defined as a “dynamic process by which hormonal, physiological, and behavioral cues are exchanged” and “reciprocally adjusted” between two or more persons (Feldman, 2012, p.42).

When considering research on synchronization, it is important to distinguish between a number of types of synchrony and imitation. Imitation results in behavior that is always similar, both in form and timing, while synchronization may or may not produce behaviors that appear the same (Koehne, Hatri, Cacioppo, & Dziobek, 2015). Both imitation and synchronization can happen spontaneously or be prescribed. Prescribed imitation and synchrony are the result of intentional action. Spontaneous synchronization may be unilateral or reciprocal. Unilateral synchronization is when one or more participants adjust their actions (produced synchrony) in response to a leader’s actions (perceived synchrony) as in a symphony following the lead of the conductor. Reciprocal synchronization is when one or more participants adjust their actions to each other, as in the case of people dancing together in an unchoreographed setting or a soccer team making a play (Cacioppo, Zhou, Monteleone, Majka, Quinn, Ball, Norman, Semin, & Cacioppo, 2014).

Concurrent synchrony is when actions happen at the same time, such as mirroring, gaze, and joint or group action. Sequential synchrony is when actions occur consecutively, as in imitation, reciprocal action and taking turns (Feldman, 2007). Dyadic synchrony is synchronization that occurs within two people, such as facial affect or speech. Triadic synchrony

is synchrony which is influenced or prompted by an external stimulus, such as music (Markova, Nguyen & Hoehl, 2019). All of these types of behavioral synchrony are believed to increase the occurrence of interpersonal physiological and neural synchrony. When behavioral and physiological and/or neural synchrony occur at the same time, it is referred to as bio-behavioral synchronization.

Types of Interpersonal Synchronization

Interpersonal Behavioral Synchronization

It has long been accepted that people tend to synchronize their activity with those around them. When two people walk together, they will eventually synchronize their gait. When a group of people are clapping, they eventually synchronize their rhythm. This “spontaneous interpersonal synchronization of rhythmic behavior” (Koban, Ramamoorth, & Konvalinka, 2017, p.2) happens more quickly with those we are aligned with, spend more time with, and/or are in close proximity to. Behavioral Synchronization can be seen between infants and caregivers, romantic partners, therapists and clients, friends, those with whom we are doing cooperative tasks with and those we perceive to be like ourselves.

Behavioral synchronization (BS) includes rhythmic synchronization, as with playing patty cake or drumming together. BS does not only include obvious actions, like clapping or walking, but also mimicking and mirroring posture, gestures, mannerisms, facial expression, tone of voice and even accent. BS is measured using a human rater-coding method (a person counting observed movements) or a computational video image method (automated counting of movements by a computer). The latter being the preferred method as it allows for much more specific, minute and accurate tracking (Schmidt, Morr, Fitzpatrick, & Richardson, 2012).

Interpersonal Physiological/Non-verbal Synchronization

When behavioral interpersonal synchrony occurs, many bodily processes may become synchronized either in-phase, (same action), or anti-phase (opposite action). Examples of bodily functions that have been observed synchronizing are: electrical and chemical neuronal activity in the same area of the brain (see Neural Synchronization), heart rate and variability, respiratory sinus arrhythmia, blood pressure, breathing, skin conductance, cardiological impedance (mechanical activity), and hormonal release (See Hormonal Synchronization) (Goldstein, Weissman-Fogel, & Shamay-Tsoory, 2017; Sterley, Baimoukhametova, Füzesi, Zurek, Daviu, Rasiah, & Bains, 2017).

Interpersonal Neural Synchronization

When behavioral or physiological synchronization is present, and in some cases even when it is not, interpersonal neural synchronization is often present or increased. Functional near-infrared spectroscopy (fNIRS) hyperscanning has been used to measure interpersonal neural activity between the brains of people. fNiRS is a non-invasive, portable way to measure brain activity by using near-infrared light to examine changes in the oxygenation and deoxygenation of hemoglobin in the cortex. (Zhou, Sobczak, Colette McKay, & Litovsky, 2020). Interpersonal neural synchronization (INS) has been found in the dorsolateral prefrontal cortex, which plays a role in cognitive control and cooperative decision making (Feng, Sun, Chen, Li, Wang, Zhang, Xiao, & Shao, 2015; Lukinova & Myagkov, 2016.) and the superior frontal cortex while doing cooperative tasks (Cui, Bryant, & Reiss, 2012). Parent–child INS was also found in the frontal pole cortex during cooperative games, but not during competitive tasks (Reindl, Gerloff, Scharke, & Konrad, 2018). INS was found in the caudate during rhythmic synchrony by means of drumming (Kokal, Engel, Kirschner, & Keysers, 2011). Movement synchrony was associated with INS in the frontal, parietal and central regions (Yun, Watanabe, & Shimojo,

2012) and in the right temporo-parietal junction, which is associated with social cognition, with tasks of shared intentionality (Tang, Mai, Wang, Zhu, Krueger, & Liu, 2016). Gamma band frequencies, which have been linked with emotion and a spectrum of social abilities that foster social connectedness such as affect (emotion) regulation, cognitive appraisal and theory of mind (Kinreich, Djalovski, Kraus, Louzoun, & Feldman, 2017) have been found synchronizing in the temporal parietal region. It is possible that activity synchronizes in other areas of the brain as well. INS research is a young, developing field and much more is yet to be tested and discovered.

Interpersonal Hormonal Synchronization

Interpersonal hormonal synchronization (IHS), or endocrine fit, has been studied between infants and caregivers, romantic couples, and clients and therapists. Oxytocin has been shown to synchronize between caregivers and infants, between caregivers of a child, between romantic couples, and between clients and therapists. Gaze (visual awareness of others) and touch, rhythmic actions, and behavioral synchrony all contribute to the increase of oxytocin synchronization between people (Kinreich et al., 2017). Oxytocin administration has been shown to enhance INS. Oxytocin administration also increases feelings of affiliation, trust, and well being, decreases pain and stress hormones, has antidepressant effects, and facilitates pair bonding, such as the connection between an infant and caregiver or between couples. It enhances social memory, such as facial recognition and increases feelings of safety and security with a partner. Oxytocin naturally increases during lactation, childbirth, orgasm, and with hugging and touch. When administered to people with disorders associated with social cognition and connection, such as Autism Spectrum Disorder (ASD), oxytocin decreases the number and intensity of repetitive behaviors, increases emotion recognition and improves social memory and social behavior. (Roopasree, Jophy, & Mukkadan, 2019).

Cortisol levels have been measured synchronizing between groups of mice (see “how does interpersonal synchronization occur”). IHS of cortisol has also been measured between romantic couples throughout the day. When one partner is under stress, the other partner’s cortisol levels rise as well. Perhaps unsurprisingly, IHS of cortisol has been associated with lower levels of happiness within the relationship (Sabe, 2017).

How Does Interpersonal Synchronization Occur?

Theories of how interpersonal physiological synchrony occurs include miniscule physical vibrations, including brain waves, acting as internal biological oscillators that transfer energy to each other, essentially pushing each other into synchronization, and mirror neurons (a class of neurons that react both when an action is executed and when a similar action is observed) becoming activated and eliciting synchronization of activity between the somatosensory cortex (responsible for somatic sensation such as proprioception, touch, temperature and pain), the motor cortex (responsible for planning and execution of voluntary movements), and the anterior cingulate cortex (responsible for many complex cognitive functions such as decision making, impulse control, social driven interactions, and empathy), of a dyad or group. (Tseng, Rajangam, Lehew, Lebedev, & Nicolelis, 2018); (Meltzoff, Ramirez, Saby, Larson, Taulu, & Marshall, 2018); (Goldstein, Weissman-Fogel, & Shamay-Tsoory, 2017); (Sanger, Muller, Lindenberger, 2012). Other theories include predictive coding and the free energy principle (optimization principle), suggesting that brains recognize, categorize, predict and in the case of IS, *respond to,* sequences and/or trajectories of sensory states as efficiently as possible *in others* as within one’s own brain (Koban, Ramamoorthy, Konvalinka, 2016; Friston and Kiebel, 2009).

In one study, a mouse was removed from its partner and put in a situation that elicited stress. When the mouse was returned to its partner, the partner’s brain showed the same corticotropin releasing hormone (CRH) activity in the brain as the mouse that received the

stressor. This activity was proven to be transmittable by the partner who did not receive the stressor to multiple partners, suggesting that some type of alarm pheromone may be a hormonal explanation for interpersonal synchrony (Sterley, et al, 2017).

Another theory is that mirror neurons and empathy play a role in interpersonal synchronization. When a person observes another in a particular emotional or physical state, the observer often has similar somatic and autonomic responses to the person experiencing the emotion or physical state. Studies show that observing another's sensory or emotional experience elicits the same or similar neural activity as when the same or a similar experience is had by the observer. (Bird & Viding, 2014). Singer, Seymour, O'Doherty, Kaube, Dolan, & Frith (2004) showed that affective parts of the brain become active with the knowledge that a friend or loved one is hurt, but somatosensory areas become active upon *witnessing* someone being hurt. Therefore, it is possible that IS may be the result of mirror neurons and the activation of somatosensory areas of the brain.

Why Does Interpersonal Synchronization Occur?

There is more than one theory exploring reasons that interpersonal synchronization might occur. Some of these theories (Hove and Risen, 2009) suggest that IS aids in survival by creating group cohesion. Specifically, there is support for the hypothesis that IS facilitates the development of language, attachment, social behavior, cooperation, and empathy (Atzil, 2017; Feldman, 2012; Markova, Nguyen, & Hoehl, 2019). Research (Holt-Lunstad, Smith, Baker, Harris & Stephenson, 2015) would also suggest that IS helps us live longer, more fulfilling lives.

Development/Attachment

It has been long understood that caregiver/child interactions in early development set the stage for language, affect interpretation, attachment, and the ability to co and self-regulate later in life. Bouts of biobehavioral synchronization between infants and caregivers result in social connection, communication, and interpersonal or co-regulation. Such IS has been linked to development of social competence, secure attachment and bonding (Atzil, 2017).

Interpersonal synchronization begins even before birth. For example, fetal movements synchronize with the mother's heart rate (DiPietro, Caulfield, Irizarry, Chen, Merialdi, & Zavaleta, 2006). IS occurs more frequently and is triggered by more processes as infancy progresses. When infants and caregivers have periods of “social synchrony”, gazing at each other and sharing similar facial expressions or similar expressions of emotion, their heart rhythms synchronize, as does their release of oxytocin. These phenomena suggest that “social synchrony” influences the development of physiological synchronization between people developing or experiencing attachment. (Kinreich et al., 2018, p1).

Periods of social gaze (looking at one another’s faces in an inverted triangular motion, following another’s gaze or alternating between looking at an object and another person) and positive affect are correlated with increased neural synchronization between (western, middle class, sighted) parents and children, and also in romantic couples. (Akhtar & Gernsbacher, 2008). Social gaze is thought to be a signal that helps the developing “social brain” to connect or get in tune with the brains of others. If there is impairment of social gaze, as with individuals on the autism spectrum, functioning of other social areas of the brain are similarly impaired. (Kinreich et al., 2018, p.6). If a person is from a non-western culture or has impaired sight, other non-gaze social cues, such as touch or verbal cues, may take the place of social gaze in establishing this interbrain connection (Akhtar & Gernsbacher, 2008).

Interpersonal synchronization is thought to be an important developmental component of learning to interpret emotion and non-verbal social cues. These interpretations, like the learning of language and rhythm, vary depending on culture, yet the overarching effects of biobehavioral IS, based on similar studies done in many cultures, seem to be universal. Mirroring of facial expressions may play an important role in how a person learns to associate emotional experiences with facial expressions (Feldman, 2012). Dumas et al (2011); Hasson et al (2012); and Markova (2019) suggest that interpersonal neural synchronization is a foundational mechanism which transmits information through both verbal and non-verbal communication. Interpersonal synchronization is thought to be an important developmental component of learning to interpret emotion and non-verbal social cues. These interpretations, like the learning of language and rhythm, vary depending on culture, yet the overarching effects of biobehavioral IS, based on similar studies done in many cultures, seem to be universal.

Infant/caregiver IS is believed to be a significant contributor to developing the skill of self-regulation. Feldman (2007) provides evidence from developmental studies that biobehavioral synchronization between infant and caregiver is one of the bedrocks of social development, particularly symbolic skills, self-regulation, and empathy.

Survival and Mortality

One theory about why interpersonal synchronization occurs is to increase the likelihood of an individual and/or group's survival. Many studies suggest that moving synchronously with others increases affiliation and it has been hypothesised that interpersonal synchronization may also occur evolutionarily to develop social cohesion (Hove & Risen, 2009). Banding together in a group to increase chances of survival can be seen in most mammals and many other species as well.

> "Social synchrony is an evolutionary - ancient mechanism that binds members into a social group; rodents and primates exhibit behavioral mimicking, a precursor of human social synchrony, and in both, familiarity with conspecific bolsters behavioral matching. Across mammalian species social synchrony is learned within the mother/infant bond through processes of bio behavioral synchrony, the coupling of parent and infant's physiology and behavior during moments of social contact and thus attachment context, provide an arena for experience and encoding of synchrony." (Kinreich et al., 2017, p.1)

Valdesolo & DeSteno (2011) suggest that the first functions of synchronization are to "mark others as similar to the self" (p.1) and to demonstrate that synchronizing with another elicits kindness and emotional responsiveness from the other. Other theories suggest that the ability to connect and feel closeness with others, which is increased by IS, decreases mortality and increases longevity (Holt-Lunstad, et al., 2015). Social isolation, loneliness and living alone increase mortality by 29%, 26% and 32% respectively. In addition, studies show that there is no difference between perceived or actual social isolation. Mortality study results remain consistent across gender, length of follow-up, and world region. Social deficits are more predictive of death in samples with an average age of younger than 65 years.

What Affects Synchronization?

Communication & Cooperative or Synchronous Activities

Singing, bouncing, rocking and rhythmic touch are naturally used by caregivers to co-regulate with and calm infants. Infants adjust their cardiac rhythms to the caregiver when lying on his or her body and also while being bounced, patted or swayed rhythmically (Markova, Nguyen & Hoehl, 2019).

Markova et al. (2019) hypothesize that rhythms of communication may have as much effect on interpersonal synchrony as external rhythms, linking one person's motor system to

another's sensory system. This suggests that the rhythm and sequential synchrony of language, rather than the words used, is a purveyor of interpersonal synchronization and that the resulting biobehavioral IS is useful for many reasons including being able to pick out a member of the group, or an attachment partner's voice in a chaotic environment. "Entrainment of internal neuronal oscillations to external rhythms enables optimal processing of rhythmic stimuli, because sensory input can then be sampled during phases of high neuronal excitability" (Markova et al., 2019, p.4) like tuning in to a radio station or being able to hear what your partner is saying in a loud place.

Researchers have found that by doing a drumming practice, the INS between participants in a group increased and that corresponding with this change, the participants felt an increased group cohesion as well as improving performance and coordination in subsequent free drumming activities. (Gordon et al., 2020). Studies have shown that walking, breathing and even pedaling a bicycle in synchrony will increase physiological and neural synchrony between participants.

Interpersonal synchronization has been shown to increase between dyads and groups during cooperative activities and when there is willing participation in these activities (Koehne et al., 2015). Some studies have shown this to be the case even while working with neurodivergent populations, such as those with ASD and schizophrenia. In one study, mothers and their children assembled puzzles together. While working cooperatively, an increase of INS was seen between mother and child.

When musicians play a piece of music together, they experience interpersonal neural synchronization. INS has been observed while people play or listen to music, play sports, exercise or watch emotional movies together, meditate in the same space and when people are participating in or observing rituals. (Goldstein, Weissman-Fogel, & Shamay-Tsoory, 2017; Novembre, Mitsopoulos, & Keller P, 2019; Sanger, Muller, & Lindenberger, 2012).

Shared Experiences

Empathy, Touch & Pain

Empathy, touch and *pain* can also affect interpersonal synchronization. Affective touch, a comforting caress-like form of touch, has been related to the sharing or transmission of emotional states and has been shown to reduce distress in infants (Hertenstien, 2006).

Bufalari & Ionta (2013) define empathy as a fundamental human social interaction that promotes the understanding of the emotions and sensations of another by sharing their sensory and emotional states. Goldstein et al. 's 2017 study researching interpersonal synchronization and pain reduction showed that being near a partner will produce IS, feeling *empathy* for them will increase it, and *touching* them will increase it more. If the partners in Goldstein's study were touching and one of them was receiving a pain stimulus, the interpersonal synchronization increased and if the partner not receiving pain possessed high levels of empathy, as tested using the Empathy Assessment Index (EAI), for the partner receiving pain and was touching her, not only were the levels of IS highest, but the person receiving the painful stimulus's pain was decreased as well. This occurrence is referred to as touch analgesia (Goldstein, et al., 2017). However, when the partners were in the same room, feeling empathy and pain was administered, but they were not touching, interpersonal synchronicity almost completely diminished. Therefore, interpersonal synchronization increases sequentially with proximity, empathy and touch when confronted with a pain stimulus. Touch decreases the pain, but if touch is removed and pain is present, interpersonal synchronization diminishes dramatically. This phenomenon deserves more attention and research.

Long et al. (2020) conducted studies that showed evidence that INS increases with romantic couples more while touch is occurring than when it is not and that this increase

correlates with feelings and strength of romantic love. This suggests that touch plays a role in affiliative pair bonding such as mutual, enduring, preferential relationships.

Altruism and Gift Giving

Even gift giving can increase interpersonal synchronization. Balconi & Fronda (2020) found that many types of prosocial behavior including gift giving and acts of altruism, can increase intrapersonal cognitive performance in the giver and interpersonal neural connectivity between the giver and the receiver. Balconi and Fronda (2020) postulate that it is this connectivity or IS that results in improvement of interpersonal relationships.

Ritual (Politics and Religion)

Because cultural practices often inform our day to day lives and influence our relationships, it is important to consider where synchronization occurs in cultural practices. Religion is filled with liturgy that involves behavioral synchronization - chanting, singing, even the common speech cadence used by many ministers are full of synchrony. Rallies and protests, sporting events and marches are all marked by chants, music and call and response.

Rituals involving rhythmic coordination such as dancing, singing, chanting or drumming, are woven through the fabric of nearly every culture, operating to foster feelings of sameness and unity and increase prosocial behavior (Fischer et al., 2013). Cho et al. (2018) conducted studies to determine if interpersonal neural synchronization increased among those in groups witnessing a ritual and what effects this would have on belief that the ritual was effective and significant. They found that synchrony does occur and that the increase in synchrony was strongly correlated with the increased belief that the rituals (religious or spiritual) were effective and significant. This has implications for group cohesion and also for understanding belief systems (both positive and negative) within groups. This knowledge can be useful while considering relationship and family therapy.

Other Considerations

Biological Sex

Biological sex appears to affect interpersonal synchronization in more than one way. In the Sterley, et al. 2017 research on mice and alarm pheromones, when the stressed mouse was placed with another non-stress receiving mouse after the stress was administered, the partner mouse (that did NOT receive or witness the stressor) would exhibit the same corticotropin releasing hormone (CRH) activity in the brain as the mouse that received the stressor. The partner (non-stress receiving) mouse, as well as the mouse having received the stressor, upon returning to their community, *both* transmitted the CRH hormonal synchrony to other mice in the community, hormonally synchronizing with the other mice, thus sharing their stress hormones and spreading their stressed response to the other mice. However, if the mouse receiving the stressor was female, and placed back in her community, her CRH activity decreased by 50%. If the stressed mouse was male, placing it with naive mice after stress had 0% effect on CRH, suggesting that both connectedness and biological sex may have something to do with IS regulation as well as recovery from stress (Sterley, et al, 2017).

Biological sex seems to make an impact on the experience of IS in humans as well. Galbusera et al. (2019), found that dyads in humans with different biological sex assignments had more interpersonal synchrony than dyads of the same assignments (while completing cooperative tasks).(p.6). Biological sex was defined as XX chromosomal patterning with “typically” associated levels of estrogen and progesterone and XY chromosomal patterning with “typically” associated levels of testosterone. Sexual orientation, gender, age, intersex persons and other instances of genetic or hormonal diversity were not addressed.

Dominance and Leading

A 2018 study by a group of researchers at Duke University showed that when a monkey is engaging in food gathering behavior in the presence of other monkeys, interpersonal neural synchronization will occur. The monkeys observing the food gatherer will synchronize with him. This study showed that INS in the reward center of the brain increased much more when a dominant monkey approached a reward (and was being observed by other monkeys) than if a non dominant monkey approached the reward. The INS peaked at about 3 feet away, illustrating again that proximity is a factor in IS and so is *social hierarchy* (Tseng, et al., 2018).

Takamizawa & Kawasaki (2019) studied the difference in INS increase in *humans* between leaders of an activity and those involved, but not in a dominant role. What they discovered is in line with data derived from studies of dominant and “follower” monkeys. The human members of a group in Takamizawa and Kawasaki’s (2019) study had the most INS with each other while watching the leader of the activity. This research may be relevant in working with groups and families, both for understanding the family or group process as well as creating activities to increase INS within the group.

Observing Touch

It is possible that just witnessing someone else being touched can elicit interpersonal synchronization. A 2018 study at the University of Washington using Magnetoencephalography (MEG) scans to measure activity in the somatosensory area of seven month old babies’ brains while they were being touched on the hand and foot. Another group of seven month old babies' somatosensory activity was measured while they were witnessing (on a computer screen) someone else’s hand and foot being touched. The “observed touch” elicited the same somatosensory activity with a slightly weaker response than the “felt touch” (Metltzoff et al., 2018). Since touch increases interpersonal synchronization and witnessing touch elicits the

same activity in areas of the brain as feeling touch, it is possible that witnessing touch may also invoke IS.

What Effect Does Interpersonal Synchronization Have on Humans?

Positive Impact

Empathy and Pro-sociality

Many studies have shown a correlation between interpersonal synchronization and empathy. Valdesolo & Desteno (2011), provided evidence that rhythmic synchronization can increase cooperation. This study showed that prescribed synchrony or imitation increases the perception that another is similar to oneself and that it will also evoke more altruistic and empathetic behavior towards the person than a nonsynchronous participant, even if the person one is matching has committed moral transgressions.

Interpersonal Synchronization has been shown to increase prosocial behavior in adults and infants (Einarson & Trainor, 2014). In Einarson's study, 14 month old infants were bounced in rhythm with adult participants, which resulted in increased IS between the infant and adult. They were then engaged in helping behaviors, for example handing the adult participant items that had been dropped. There were much higher levels of altruistic behaviors in the infants who had been bounced synchronistically with the adult participant than those who had been bounced a-synchronistically with her.

"A growing body of research provides evidence for social consequences of interpersonal synchrony by showing association with greater rapport, prosocial behavior and cooperation." (Valdeso, Ouyang, DeSteno, 2010, p.2). There is evidence that produced synchrony boosts feelings of empathy and affiliation for another. This occurs even in participants with autism spectrum disorder if the activity is engaged in willingly (Koehne, et al., 2015). Similarly to

produced synchrony, perceived synchronization has also been shown to increase feelings of empathy, and affiliation.

Pain Reduction/Tolerance

Goldstein et al. (2018) found that if two people hold hands during pain, the brain to brain synchrony between them increases and that this increase correlates not only with pain relief, touch analgesia, but with the amount of pain relief and the accuracy of the non-pain receiving partner's empathy towards the person receiving pain. Cohen (2010) found that after a period of high-intensity synchronous rowing, participants exhibited decreased pain and elevated pain thresholds and that the pain thresholds of the rowers participating in a synchronous action surpassed those participating in an equivalent solo rowing experience.

Feelings of Connection and Affiliation

IS is believed to increase the liking or and feeling of closeness to others. Hove & Risen's 2009 article draws a correlation between interpersonal synchronization (as opposed to mimicry) and affiliation or liking the person you are synchronizing with.

A researcher, McNeil, in 1995 observed what he called muscular bonding which was experienced during military drilling - interpersonal rhythmic movement which resulted in increased feelings of connection and self-assessment ratings. (Lumsden, Miles &, Macrae, 2014). Lumsden et al. 's (2014) study also has findings that revealed that interpersonal synchrony has an effect on self-esteem. Individuals feel better about themselves following a period of synchronous compared to asynchronous movement. IS appears to have an effect on how much one likes both others and one's self.

Interpersonal synchrony increases feelings of connectedness and blurs the self- other boundaries between interaction partners. Valdesolo & Desteno (2011) showed that prescribed synchrony increases the perception that another is more like one's self than a

non-synchronizing participant, even if the synchronous partner exhibits behavior one is morally opposed to. Rabinowitch and Knafo-Noam (2015) provide evidence that IS between children increases perceived similarity and closeness towards each other.

Negative Impact

Need for Balance

Despite many benefits, more synchrony is not always more beneficial. Evidence from developmental studies show that parent-infant synchrony is a cornerstone of social development, and most particularly crucial for the development of self-regulation, empathy and symbolic skills (Feldman, 2007). However, healthy, stable systems do not maintain a constant level of rigid synchrony. “Synchronization may sometimes relate to homeostatic -stable (morphostatic) processes and at other times to developing and changing patterns (morpho-genic) (p.2).

It seems that moving in and out of synchrony can be adaptive both developmentally and in relationships later in life. An adaptive interpersonal system is flexible and capable of adjusting to social context. Parents and children tend to move in and out of sync (Feldman, 2007). Developmental studies demonstrate that middle level synchrony between parent and child is associated with more secure attachment (Beebe & Steele, 2013). In the exploration of attachment between people of any age, more secure attachment was not associated with constant synchrony, but with a back and forth process, synchronous at times and not at others. Secure individuals may feel able to disengage with synchrony under the assumption that they will be able to re-engage easily. Too much synchrony may decrease the ability to self regulate. While it was found that synchrony was related to increased positive affect it was also related to decreased self-regulation (Beebe & Steele, 2013).

Complex dynamical systems approach may be a model that can help us understand this process of moving in and out of synchrony. “Complex dynamical systems are defined by three main characteristics 1. They consist of several interacting components. 2. “Emergence”, which is the collective behavior, takes some kind of pattern which can’t be extracted by considering only one component. 3. The pattern is self organized and doesn’t require internal or external organization.” (Mayo & Gordon, 2020, p.4) Self-organizing or complex dynamical systems can be seen in many functions of an organism. They can be evidenced in biological and neurological homeostasis and the interplay between sensory input and motor functions. They occur in electrical firing of a heart as well as the complex cardiovascular system as a whole. They also occur beyond the individual organism, at the social or collective level. (Goldstein et al., 2017).

Galbursura et al. (2019) build on the idea of a complex, self-organizing system and suggest that while interpersonal synchronization feels good at higher levels, more constant levels of IS predicts more difficulty with self-regulation of emotion.

> "In an act of cognitive science: the human self, for its stability and regulation, relies on both, individual bodily and interactional self-organizational loops. Importantly however, in order to maintain a stable self, agents need to structure their entrainment and social interaction dynamics so as to also allow for moments of Independence and disengagement. The human self is, at its core, neither completely attuned to nor separated from the social environment, but integrates both dimensions instead. Not balancing them can have negative effects. As research on solitary confinement has shown, a lack of social engagement can have severe consequences for a person's sense of self and regulation capacities. But by the same token, an excess of social attunement and synchrony might lead to dysregulation and instability of the self as well." (Goldstein et al., 2017, p.2).

The foregoing is called the trade off hypothesis. It implies that harmony with others is not all we need for stability. That we also have the need to balance our reliance on others with separation and independence from them.

This supports the theory that both periods of interpersonal synchronization and autonomy are needed in early development in order to develop the ability to self regulate, and likewise supports the theory that in romantic relationships, too much interpersonal synchrony with no periods of autonomy can create an unhealthy enmeshment. Goldstein et al (2017) speaks to the deeply social nature of the human self, but also shows that strong entrainment of the self in social dynamics can have a negative impact on a person's self-regulatory ability. "When we rely on others to regulate our emotions, we outsource some of the load of our self-regulatory effort into the interaction." (p.8). This concept is similar to Bowen's "differentiation of self", in which he suggests that maturity is the state of being able to think as an individual and self regulate while remaining connected to others. Bowen believed that if the system, in his theory the family, protected, or regulated for one member, then that member would not learn to regulate for themselves and that would result in an unhealthy system and the individual not being able to reach maturity. (Mahmodimehr, M. & Bahari, F, 2013).

"The human capacity for self-regulation might depend more on social interaction dynamics than on individual processes. It has been widely recognized that interpersonal engagements and synchrony are vital for the regulation of the self in the early developmental stages." Goldstein et al's (2017) study shows that adults also rely on social interactions for self-regulating and modulating their emotions. (Goldstein et al., 2017) However, we must consider a more nuanced understanding of the interplay between the group and individual levels of regulation. Self-organization also plays a critical role in the stability of self. Miscoordinations

and repairs in interpersonal synchronization seem beneficial for developing self-efficacy and self regulation skills.

Compliance with Aggression and Conformity

It has been shown that in addition to increasing altruistic behaviors interpersonal synchronization boosts compliance to requests for aggression from those one is synchronizing with. In fact, only mechanical synchrony needs to have occurred for this to be true. Wiltermuth (2012) demonstrated that cultural practices which included behavioral synchrony bound people together, which resulted in participants being more likely to act aggressively and engage in harmful acts against others. “Increased social connection partially mediated the link between synchrony and enhanced compliance. Synchrony therefore seemed to elevate the importance of complying with the requests of those within the synchronous group over the importance of adhering to the social proscription against unprompted aggression.” (p.455) In Launay et al’s 2013 study, they found that synchronous activity has been shown to increase cooperation among both children and adults, encourage compliance and conformist behavior, and boost trust (Launay et al., 2013). Therefore interpersonal synchronization not only boosts pro-social behavior, but also trust, compliance with harmful requests and aggression by group members.

Therapeutic Considerations/ Potential Applications

Therapists are in the unique situation of having a profession that puts them in the position of providing support to near strangers for recovery and personal growth. The importance of the therapeutic alliance is stressed in counselor training programs. Kykiri et al.

(2019) shows evidence that behavioral synchrony (hand movements, postures, facial expressions) which leads to IS, increases the therapeutic alliance as well as the alliance between participants. Schoenherr et al. (2019) presents evidence that when there is more nonverbal synchronization (which results in increased INS), a client with social anxiety disorder, a disorder that results in achieving IS less often, is more likely to continue therapy for the entire course of treatment.

Teaching Empathy

Producing synchrony could open up new techniques for teaching empathy and working with populations with Autism Spectrum Disorder. Koehne et al. (2015) presented a study that provides evidence that perceived IS increases empathy in participants on the autism spectrum. After following the finger tapping pattern of a leader for a prescribed amount of time, the participant showed increased interpersonal synchronization and increased empathy towards the leader as well as increased ability to correctly interpret facial expressions. Intentional synchrony may increase the capacity for empathy in the neurotypical population as well. As mentioned in the section above, Positive Impact - Empathy and Prosociality, imitation, produced synchrony and rhythmic synchronization all increase empathy. (Valdesolo & Desteno, 2011).

Virtual IS experience

Virtual communication, teletherapy, and virtual reality may provide new ways to develop IS, increase oxytocin and foster the feeling of connection. One study showed that produced interpersonal synchronization increased empathy and alliance even when the lead partner was known to be a computer simulation (Koehne et al., 2015). Another showed that a baby's brain produces similar activity when the baby is touched as when the baby observes another person being touched on a computer screen (Metltzoff et al., 2018).

The Meltzoff et al. study (2018) demonstrated that just witnessing another being touched can activate areas of our brain that activate when we are touched. Studies like these could open up possibilities for developing treatment modalities to increase INS and oxytocin levels not only with physical touch, but also virtually (particularly for those who may have an underdeveloped somatosensory system). The COVID 19 pandemic has made it more clear than ever that it is important to create ways of reducing loneliness and social isolation that are not dependent upon in person modalities. Virtual communication and also virtual reality programs have the potential to help those who, for whatever reason, cannot be touched.

Conclusion

Synchronization occurs spontaneously throughout nature and can be seen in the rhythmic flashing of fireflies, the coordinated movements of schools of fish, the complex neuronal firings in the brain and internal and external interactions between human beings. Interpersonal biobehavioral synchronization (behavioral, physiological, neuronal and hormonal) IS the biology of connection. In humans, interpersonal synchronization can increase empathy and feelings of prosociality, increase pain tolerance and induce touch analgesia. IS can create feelings of likeness and connection, develop trust and attachment between infants and caregivers as well as romantic partners, and under some circumstances those who do not know each other well and/or have only interacted virtually. Periods of synchronization combined with unsynchronized periods create the ability to co and self-regulate and lead to secure attachment bonding. Ritual, touch, gender, and dominance or leadership all have an impact on the experience of interpersonal synchronization. Much more research is needed in this relatively new field. However, the research presented here suggests great potential for new ways of approaching mental health and the development of new, effective, treatment modalities and

practices in the fields of psychology and counseling through the use of interpersonal synchronization and biological connection.

A few such potential applications follow: The fact that touch is frowned upon in the fields of psychology and counseling, as well as other health professions, can be a hindrance to forming the therapeutic alliance and aiding recovery. Interpersonal synchrony, which increases alliance and cooperation decreases in the presence of pain without touch. Research on IS, pain and touch could open up pathways to new forms of treatment incorporating appropriate, healthy touch into the field of mental health and health care professions in general. Based on the research presented here it is reasonable to believe that doing cooperative tasks or synchronized activities in therapeutic settings could increase the therapeutic alliance and increase the likelihood of continuing therapy.

Long et al. (2020) explained that INS increases with romantic couples more while touch is occurring than when it is not and that this increase correlates with feelings and strength of romantic love. This suggests that touch plays a role in “affiliative pair bonding”. The studies discussed in this paper suggest that participating in activities which increase IS will lead to a corresponding increase in connection, empathy, affiliation and prosociality. Some studies suggest that the process moving in and out of synchrony with each other can promote not only co-regulation, but the learning of self-regulation as well. IS increases the liking of others and feeling good about one’s self. This writer suggests that drawing from the combined findings of this research, we can develop effective forms of non-talk therapy that can help couples, families and groups increase INS and affiliative pair bonding.

Much research has been done on the effects of IS in dyads, but not as much research has been done on groups. An investigation of the effects of increasing INS in groups found that by doing a drumming practice, the INS between participants in a group increased, and that with this increase, the participants felt an increase in group cohesion as well as improving performance and coordination in subsequent free drumming activities. (Gordon et al., 2020).

This reader proposes that based on the conclusions drawn from the research compiled in this paper, participating in activities that increase IS in dyads and groups can improve cohesion and cooperation within groups and dyads.

The research on virtual reality may also encourage the development of new methods to work with those resistant to touch or who have had early developmental neglect and/or those who have an underdeveloped somatosensory or anterior cingulate cortex.

The research presented in this paper supports the hypothesis that inducing a combination of interpersonal synchronization and breaks from synchronization through the use of music, rhythm, touch, side by side counseling, movement, and other synchronistic activities, can be used to promote empathy, alliance, cooperation and secure attachment and might also be used in innovative ways to decrease pain and retrain behavior. Having strong healthy connections with others is an indicator of longevity, health and happiness. This new area of research on interpersonal synchronization opens up opportunities for more research and new approaches to mental health treatment.

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