THE BEAT, THE WEBCAM, AND THE DILEMMA: WHAT TRUST HAS TO DO WITH RHYTHM
AND VIDEO-COMMUNICATIONS

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ABSTRACT

Previous studies have shown that joint music-making tasks can elicit higher levels of cooperation and trust in populations of adults and children. The first aim of our experiment was to determine whether rhythm, as a vital but separable component of music, could produce the same effects. We found that subjects who clapped in synchrony with one another perceived their partners as being more trusting than did those who clapped in asynchrony, suggesting that joint rhythmic tasks may facilitate relationship building and maintenance. Our second aim was to study what modulatory effects a video-communications medium might have on this rhythmic influence on trust. Subjects who were placed in separate rooms and completed the rhythmic tasks with the aid of a webcam, headphones and a microphone, demonstrated a marginally significant increase in trust towards their partners. We hypothesize that either some aspect of the technology itself or an alteration in social interaction style as a result of the novel interaction medium is responsible for this effect.

INTRODUCTION

Neural evolution of music

Much of the neurological circuitry underlying musical processing is poorly understood, and the evolutionary roots of music are even more mysterious. Though scientists have made enough headway in identifying neurological correlates and cognitive constructs of music to come to a rudimentary understanding of the mechanisms involved in its production and processing, myriad theories as to the evolutionary origin of music-making as a uniquely human attribute have been posited. Many viewpoints, both old and new, are hotly debated in the literature and include theories that music developed as a precursor to speech (Darwin, 1891), as a happenstance byproduct of speech (Pinker, 1997), as a mate-attracting display (Darwin, 1891, 1909; Levitin, 2006), or as a result of advanced memory adaptations in humans (Balter, 2010). Another approach to this research area has been to examine specific aspects of the evolutionary basis of music without presupposing a given theory, and then attempt to map experimental findings onto a complimentary model. For example, a recent case study has found that infant chimpanzees may prefer consonant music over dissonant music (Sugimoto et al, 2010). As humans also generally exhibit this preference, this finding suggests a pre-*homo sapien* root to features of music processing found in modern humans. Thus, while this study lacked a theoretical agenda, its results are generalizable enough to lend credence to some origin of music theories and discredit others.

One theory that has found support from a variety of researchers is the idea that music facilitates social bonding and group cohesion. This theory has been difficult to discredit, as it is not mutually exclusive with many of the other theories. For example, it is possible or perhaps even evident that music can facilitate both sociability and sexuality, or have originated as a byproduct of speech, but persisted as a result of its beneficial effects on group dynamics.

Because of the ease with which the music-facilitates-sociality hypothesis can be adapted to compliment the assumptions of other origin of music theories, it is one of the most convincing. Thus, it is the aim of the current study to extend this line of research by examining the effects of rhythm, a vital component of music, on interpersonal trust and cooperation. Our experiment will utilize two specific interaction contexts, a "live" face-to-face context and a video and microphone-aided "virtual" context. This approach will also allow us to study how the relatively recent advent of video-communications technology can modulate an adaptive aspect of music that is assumed to be at least as old as the development of speech, and potentially much older. Little research has been done into how video

technology modulates human interaction, so this aspect of the study is interesting in its own right.

Rhythm and cooperation

Though the term "rhythm" can be used to describe the distribution of any element over time (i.e., the rhythm of migratory patterns or brainwaves), in the case of music it specifically refers to the temporal organization of sound. Rhythm is considered by some to be the most important aspect of music because, as a time-dependent entity, music cannot possess structure without it (Thaut, 2005). Given the wealth of studies on the neurological and behavioral effects music can elicit, including cortical reorganization (Jäncke, 2009; Groussard et al., 2010), memory modulation (Carney and Levin, 2007; Groussard et al., 2010), and a wide variety of emotion-related phenomena (Graham, Robinson and Mulhall, 2009; Filipic, Tillmann, and Bigand, 2010; Koelsch, 2010), it is surprising that rhythm, as such an integral aspect of music, has been relatively under-studied by neuroscience compared to its sonic cousins, melody and harmony (Overy and Turner, 2009). Partly because of the scarcity of rhythm-specific research as compared to more general music research, rhythm is the primary musical focus of the current study.

Another focus is cooperation, which has been defined as the act of working to maximize the payoff of all parties involved in a social situation (Eek and Gärling, 2006). Though neuroscientists have only recently begun to elucidate the neural correlates of this process (which will be discussed in a later section), psychologists have been studying cooperative behavior for the better half of a century. Because the ability to effectively cooperate is a hallmark human trait (Eek and Gärling, 2006), studies in this area have implications for a wide range of fields, from interpersonal relationships to economics, military tactics and global politics (Simpson, 2004; Wiltermuth and Heath, 2009).

The current study builds on the limited amount of previous research examining how music can modulate cooperativeness in non-musicians. An early experiment in this vein (Anshel and Kipper, 1988) consisted of having groups of males watch a documentary, listen to music, read poetry, or sing together. After completing these tasks, each individual completed a questionnaire about the trustworthiness of the other members of his group, and participated in the Prisoner's Dilemma, a game which is designed to measure cooperativeness. An analysis of the results of the game and the survey found that those groups that either listened to music together or produced music together by singing tended to act significantly more cooperatively than the other groups. The researchers also found an insignificant trend toward an

increase in trust as a consequence of the musical tasks, and suggest that this trend may become significant under different testing circumstances.

Indeed, a subsequent study (Wiltermuth and Heath, 2009), found that group singing significantly increased both trust scores on surveys as well as performance in cooperation exercises. In two of the three experiments described in this study, participants were grouped in one of four conditions: a synchronous singing and moving group, which sang together while listening to music through headphones and moved cups in time to the music; an asynchronous singing and moving group, which performed the same task, but at different tempos for each member of the group; a synchronous singing only group, which held a cup still while listening to music through headphones and singing together; and a control group, which listened to music through headphones while holding a cup and reading the lyrics to the music. The researchers found that participants in both synchronous tasks cooperated more in a group exercise and trusted one another more (as measured by survey responses) than members of the asynchronous and control groups. This effect was stronger than that elicited by common identity and common fate, two other contributors of enhanced cooperation, and was present even when the cooperation exercise was altered so that cooperating produced substantially less monetary compensation than acting selfishly. The fact that there was no difference in these measures between the two synchronous groups indicates that it was the musical synchronization, not the physical motion of moving the cups, which elicited the effect. In the third experiment in this study, cooperation and trust was boosted after participants spent time walking in step with one another. This suggests that synchrony need not be manifested in a musical form to elicit cooperative and trusting behavior.

At first glance there may seem to be a disparity between the finding that synchronous cup-moving did not enhance cooperation and trust, and the finding that walking in step increased both. Because both behaviors involve synchronized large-scale movements, it is tempting to classify them as equivalent actions. However, two vital differences should be noted. First, the cup-moving task made no noise in and of itself, while walking presumably made some limited amount of noise. It is possible that this synchronized auditory cue could play a role, as auditory cues were, of course, prominent in the synchronized singing tasks that did produce an effect. Secondly, the participants in the cup-moving task synchronized their movements to the tempo of the music playing through their headphones. For the walkers to synchronize with one another, they had to observe one another's movements and constantly adjust their own to stay in step. It seems likely that this increase in interpersonal engagement could influence trust and cooperation levels.

Another recent study (Kirschner and Tomasello, 2010) provided evidence that music-modulated

cooperation may have evolutionary roots by studying children. The logic behind this choice in demographic was that young children lack the sexual drive and socially-produced concepts of music that are central to some theories of the origin of music, so by testing young children the researchers could narrow down the number of possible models that could be used to explain their findings. Here, 4-year-olds were led by experimenters in a series of either musical or nonmusical activities under the pretense of playing a make-believe game. The musical group sang, played simple instruments and danced with the experimenter, while the nonmusical group completed tasks that approximated the same level of vocal and motor output of the other group but in a decidedly unmusical context, such as walking, crawling, making frog-like vocalizations and physically manipulating toys. After this priming, pairs of children played two games. The first was designed to measure the helpfulness of the participants, and involved transporting marbles across a room in special cylinders. However, one of the children in each pair of partners had a rigged container that would fail at some point during the game, causing the marbles to spill all over the floor. How the other child responded to this incident—whether they helped to retrieve the stray marbles, and the latency with which they did so—was interpreted as indicating the responding child's propensity for helpfulness. The second game revolved around an apparatus which could be used either cooperatively or independently in the completion of a task. The manner in which the children decided to use this apparatus measured spontaneous cooperation between the individuals. Rigorous procedures for interpreting the behavior displayed in these tasks helped establish reliability of the finding that the musically primed group cooperated significantly more than the control group in both of the cooperation games.

In addition to the studies described above, there is a good deal of literature suggesting that non-musical synchrony may induce or be associated with cooperation, trust and other prosocial qualities between individuals or groups. These studies have used primers ranging from innocuous physical tasks synchronized between strangers, such as rocking in chairs (Valdesolo, Ouyang, and DeSteno, 2010), to more complex interpersonal interactions, such as mothers talking to their infants (Bernieri, Reznick, and Rosenthal, 1988) and teachers interacting with their students (Bernieri, 1988). Taken together, this literature suggests that synchronization can boost cooperation levels. One aim of the current study, therefore, is to examine whether this effect can be observed in a situation where the synchronized activity consists of an exclusively rhythmic task which lacks the melodic/harmonic auditory aspect of a fully musical task, and which also lacks the synchronized large-scale movements (marching, rocking, walking, etc.) of previous studies. Minimizing the movement aspect should help to determine whether rhythmic synchronization is the cause of any significant effects we observe.

Synchronization and rhythmic processing

Neural processing of rhythm is distributed across many brain regions including cortical, subcortical, and cerebellar structures. Though brain imaging studies have revealed much about the nature of these rhythmic networks, a cohesive, complete description of the process is hard to produce because not only does it involve a large number of widely distributed regions, but these structures interact in varying and, in many cases, still poorly understood ways. When and why different structures are activated and interact with one another depends not only upon the aural stimulus itself, but on the motor response from the subject, the subject's rhythmic knowledge, and the structure of the specific rhythm presented. In fact, different networks may be activated in response to varying stimuli in different individuals, depending on their experience and expertise with rhythm and music (Thaut, 2005). Because of the breadth of complex neurological processes involved in rhythm perception in general, the current discussion will focus largely on the cognitive and neural correlates of *synchronization*—that is, the mechanisms by which the brain processes incoming rhythmic stimuli and produces a rhythmic response with the same temporal organization as that stimulus, usually simultaneously with the stimulus. The response that the brain produces may be in the form of an overt behavioral rhythmic expression, such as clapping or dancing, or an internal physiological expression, such as the rhythmic firing of a neural network. The internalization and reproduction (either behaviorally-physically or neurologically-physiologically) of an external, modulating rhythmic source is known as *entrainment* (Thaut, 2005). Though the current study does not experimentally address the cognitive and neural underpinnings of rhythm and entrainment processing, an overview of this material is here presented as a foundation from which to better understand the possible mechanisms underlying the experiment.

In behavioral studies of entrainment, two objective dependent variables are analyzed: the inter-response interval (IRI), or the amount of time that elapses between each unit of rhythmic output from a participant (i.e. a clap, a step, or a finger tap), and the synchronization error (SE), which is the timing delay between any single stimulus from the external rhythmic pattern and the counter-stimulus from the subject (Thaut, 2005). Scientists tracking these variables in subjects finger-tapping in time with metronomes identified two distinct strategies for entrainment (Thaut, Miller and Schauer, 1998). When a previously steady beat was quickened or slowed by an imperceptible amount, the participants quickly matched their IRI to the new delay between external beats (inter-stimulus interval, ISI), temporarily

increasing their SE. Once the IRI had been successfully matched to the new ISI, the SE slowly renormalized to a more precise level. However, when the beat was altered by a perceptible amount, subjects utilized the opposite strategy—first SE was quickly adjusted to the new beat, then IRI was corrected. Additionally, increases in ISI (a tempo decrease) were met with more efficient adjustment in both the imperceptible and perceptible tempo change conditions than were decreases in ISI, as indicated by the fewer beats taken on average in the former condition to synchronize to the new beat. From these findings, and the observation that their subjects could entrain a rhythm within 1-3 repetitions of the IRI, the authors conclude that the brain possesses the ability to quickly and fluidly create or manipulate cognitive rhythmic templates on which the temporal organization of physical behavior is mapped, and that it can do so on either a conscious or subconscious level.

Further research in this vein has featured similar experimental setups, but with different parameter manipulations. For example, in a study that utilized a metronome with a cosine-modulated ISI, such that the tempo varied slightly from beat to beat, subjects used similar strategies as the ones described above and were equally successful at entraining, even in response to sub-perceptible tempo changes (Thaut, Tian, and Azimi-Sadjadi, 1998). The consistency with which subjects entrain to imperceptibly modulated rhythms suggests that brain regions largely involved with processing above the consciousness threshold are not necessarily involved in entrainment.

In explaining these entrainment strategies from a cognitive standpoint, scientists have conceptualized a nonlinear executive controller as a feature of the rhythmic synchronization networks in the brain (Thaut, 2003). This controller is capable of utilizing various synchronization strategies contingent upon the specific qualities of a given entrainment system. As was just related, when responding to a perceptibly varying ISI, the dominant strategy selected by the controller is to first quickly adjust SE in response to tempo change before slowly adjusting IRI, while when responding to an imperceptibly varying ISI, the controller opts to first correct IRI, then SE. Other aspects of the cognitive entrainment system are governed by more qualitative strategies. When performing an exclusively internally synchronous task that lacks external stimulus cues, such as walking at a regular gait or finger-tapping without a metronome, the IRI has been observed to exhibit small perturbations over time which vary in a deterministically chaotic manner. However, when these behaviors are executed with the continual guidance of a metronome, the nonlinear perturbations are replaced with truly random fluctuations that nevertheless also exhibit some long-range correlations in SE (Roberts, Eykohlt, and Thaut, 2000). Because these innate random fluctuations occur below the threshold of tempo change awareness, which is generally considered to be about 5% of ISI, some scientists have postulated that

they are simply the noise of an inherently imperfect neuromuscular system. Other researchers have suggested that these perturbations actually facilitate effective entrainment to dynamic stimuli and are integral to the system (Thaut, 2005). While researchers are yet to understand what mechanisms are responsible for the nonlinear and truly random synchronization modes, or what purpose these modes have in the synchronization process at large, their presence is indicative of the existence of a variety of entrainment strategies, seemingly developed to cope with diverse stimulus elements.

Thus, a reasonable cognitive framework for synchronization has been conceived. In an effort to elucidate the neural correlates of the process, researchers took the finger-tapping paradigm a step further, and used magnetoencephalography (MEG) technology to monitor the brain waves of their subjects while the task was being completed (Tecchio et al., 2000). This experiment showed that the amplitude of the M100 potential evoked in response to the changing metronome stimulus was positively correlated with the length of the ISI, and this relationship was exponential. This occurred whether the ISI was altered perceptibly (by 20% of the base ISI) or imperceptibly (by 2% of the base ISI). Amplitudes of brain-waves are proportional to the number of neurons firing in unison in a given network, so this finding implies that more neurons fire in a coordinated fashion in response to ISI lengthening while fewer fire in response to ISI truncation. Using dipole analysis, the researchers found that the M100 potential was generated in Heschl's gyrus in the auditory cortex, indicating that this region plays a direct role in both conscious and unconscious entrainment.

A subsequent experiment using a similar finger-tapping task recorded brain activity with positron emission tomography (PET), and identified a wide variety of brain regions differentially activated by rhythmic tasks (Stephan et al., 2002). The experimental setup included isochronous (non-modulated) rhythmic stimuli as well as rhythmic patterns with ISIs modulated by 3%, 7%, or 20% of the base isochronous ISI. At the 3% level, no subjects reported awareness of any alteration to the stimulus, at the 7% level some subjects detected some alteration to the stimulus, but none could identify the temporal aspect as being the target of that alteration, and at the 20% level all subjects reported noticing a temporal change in the stimulus. Strikingly, the researchers found that more brain regions were recruited as temporal disturbance increased such that the 3% condition featured activations in ventral medial prefrontal cortex, thalamus, inferior parietal lobe, and caudate, while the 7% condition elicited all these activations, plus ventral lateral prefrontal and cerebellar responses. In turn, the 20% condition, in addition to these areas, featured activation of the dorsolateral prefrontal, anterior cingulate and lateral premotor cortices.

Excepting the cerebellar involvement for the moment, this pattern of activation can be better

described as an expanding activation of prefrontal regions, going from medial to ventrolateral to dorsolateral prefrontal activations as the magnitude of the ISI disturbance increased from a sub-perceptible to a semi-perceptible to a fully perceptible level. The orbitofrontal and ventrolateral prefrontal activations common to all three conditions are associated with sensory information processing, implicit memory, quick automatic learning, stimulus association, and temporal-contextual memory—all functions which may operate on a non-explicit processing level. A comparison between the activations in the brains of those subjects in the 7% condition who reported an unidentified change in the stimulus and the activations in the brains of those who did not notice a change revealed that awareness of a temporal disturbance was associated with preferential activity in the putamen, insula, cingulate cortex, supplementary motor area, and dorsolateral premotor cortex. The occurrence of dorsolateral prefrontal activity in the aware subjects in the 7% condition as well as in all the subjects in the 20% condition strongly suggests the involvement of this area in conscious processing of incoming rhythmic data.

By subtracting recordings of regional cerebral blood-flow activations in subjects simply listening to an isochronous rhythmic stimulus from the activations observed in the brains of subjects tapping along with the stimulus, researchers were able to uncover the rather complicated neural network underlying isochronous rhythmic synchronization (Thaut, 2003). The areas activated in this task include primary sensorimotor cortex, superior frontal gyrus, cingulate motor areas, ventrolateral prefrontal cortex, and dorsal and ventral premotor areas. In addition, several topographically small but statistically significant activations were observed in the anterior insula, opercular parietal lobe, thalamus, putamen, and cerebellar regions including right cerebellar vermis and the anterior hemispheres. Additional posterior cerebellar activations were observed when subjects entrained to a cosine-modulated rhythmic pattern. The intriguing end result of this study was the discovery of an intricate neural network underlying synchronization processing, featuring widely distributed brain regions that appear to interact in a cooperative and internally synchronized manner such that cerebellar and prefrontal regions are able to fire in a temporally related fashion.

In an effort to further understand this rhythmic processing network, researchers focused on examining the function of the cerebellum with respect to rhythm processing, as this region was activated in many of the conditions of the PET study. (Molinari, Leggio, and Thaut, 2007). One experiment (Lebrun-Gillaud, Tillmann, and Justus, 2008) had patients with cerebellar damage make subjective judgments as to the rhythmic regularity of short musical passages that were manipulated to be either rhythmically regular or irregular. While the patients were able to differentiate between the two

rhythmicities, they perceived the irregular stimuli as being qualitatively more regular than did a group of matched controls. The general reduction, but not elimination, of the patients' ability to analyze rhythms in this experiment is indicative of a reduction in the ability to process rhythm as a consequence of a damaged cerebellum. These patients were also sensitive to rhythmic manipulations in another experiment in which two possible timbres were used to play the final chord of the musical passage. In this case, the patients could only differentiate between the two rhythmicities when the final chord was played using the timbre that was less related to the timbre of the preceding passage. The authors hypothesize that in order to differentiate between the regular and irregular rhythms in the alternate timbre experiment, patients did not rely on rhythm processing so much as timbre processing—the unusualness of the final timbre combined with the limited rhythmic processing power the patients retained was enough to allow them to correctly identify the rhythmic nature of a given passage. Indeed, in a third experiment the patients showed equal melodic processing abilities as a matched control group, showing that cerebellar damage had no effect on this faculty. Thus, it is likely that the patients' ability to differentiate between the two timbres was unimpaired, and that this allowed them to supplement the rhythmic information they missed with different auditory cues, or "surface markers," which may indirectly increase the brain's responsiveness to irregularity or novelty.

Overall, these studies have provided a fair amount of evidence that the cerebellum plays a significant role in synchronization processing. However, the fact that rhythmic judgments were not fully abolished as a result of cerebellar damage in the above study, together with other findings suggesting the involvement of myriad other neural mechanisms in timing processes, including the primary motor cortex (Renoult, Roux, and Riehle, 2006) and a variety of distributed networks (Jantzen, Steinberg, and Kelso, 2005), indicate that timing and synchronization processing probably arise as a result information exchange between all of these regions, with no single region being responsible for the entirety of time processing. It is theorized that the temporal precision with which these distributed networks fire in parallel with one another is responsible for their success in rhythm processing (Thaut, 2003).

Models exist which may provide a tentative basis for the cellular dynamics of these networks. By expanding the rule set governing neuronal interaction in an otherwise standard, randomly connected artificial network, to include temporally sensitive neuronal activation patterns, one team of researchers was able to produce a network that was capable of spontaneously discriminating between arbitrary frequencies of pulse inputs (Buonomano and Merzenich, 1995). Traditional artificial networks only use the most basic modes of neural behavior to define node interaction within the network—post-synaptic potentials (PSP) summate, producing a post-synaptic action potential or pulse propagation, provided the

summed PSPs reach a given threshold. This interaction rule is known as *integrate-and-fire.* In this study, however, the researchers included two additional rules that have been observed in natural cortical networks: paired pulse facilitation (PPF) and slow inhibitory post-synaptic potentials (IPSPs). PPF occurs when the second of two pulses in an input train individually produces more post-synaptic excitation than it would have were it not preceded by the first pulse, and slow IPSPs are a result of simple inhibitory modulations to excitatory neurons that result in an extended inhibition of the modulated neuron. While integrate-and-fire networks, by the nature of their mechanics, are mostly sensitive to spatial information, the dynamics of PPF and slow IPSPs allow a system including these rules to be impressively sensitive to temporal information as well. As a result of this property, the network in this study was able to spontaneously differentiate between pairs of pulses with a variety of delays, between trains of pulses at different frequencies, between sets of random stimuli, and even between phonemes. It is the ability of such a system to so easily generalize its processing capabilities to diverse tasks that make this model an attractive framework for understanding *in vivo* neural rhythm processing.

Oscillator coupling, wherein the firing one neural network may spontaneously entrain the firing of a spatially distant network via physiological resonance, has also been proposed as a mechanism for the coordination observed in the rhythmic processing system (Thaut, 2003). It is possible that both these explanations are valid, as they both describe aspects of the system well, and are not fundamentally mutually exclusive.

Neural correlates of cooperation and trust

Trust has been shown to activate the septal area (SA) and paracingulate cortex (PcC) in brain imaging research studying pairs of individuals interacting in a social game which revolved around making choices to cooperate or defect with one another (Krueger et al., 2007). The Prisoner's Dilemma-like game used in this experiment was similar to the one used in the current study—in each round the participants made a choice of whether to defect or cooperate, where the choice to defect tended to yield higher personal gain in payment at the end of the experiment, and cooperating yielded the greatest combined payment to both players. Choices were made in turns between the two players, so making a cooperative choice (and consequently leaving oneself vulnerable) was the same as making the decision to trust the other player not to defect. From analyses of fMRI scans taken of each subject while

participating in the game, the researchers found preferential activation of the SA and PcC while subjects made trusting choices. By dividing the pairs into two groups depending on their trust tendencies, the researchers could make further analyses. One group consisted of all the pairs that had never defected, while the other group contained pairs that had players who had defected at least once. Statistical analysis of Likert scale surveys found that pairs in the non-defecting group felt closer to one another after completing the game, made significantly more trusting decisions than the defecting group, and experienced an increase in cooperative decisions over time. In contrast, the number of trusting decisions made in the defecting group decreased over time and was most frequent in low-payoff games.

In order to study the dynamic activation of the SA and PcC over the course of the development of the relationship between each pair, the scientists arbitrarily divided their data into two sets per group—a "building" stage and a "maintenance" stage. The building stage represented the first half of the total number of cooperation games each pair played, as it was assumed that during this time each individual was forming a mental representation of their partner. The second half of trials was referred to as the maintenance stage, as it was assumed that each player had become somewhat familiar with their partner, and that the relationship was now being maintained, rather than established. A region of interest analysis revealed that the PcC was more active during the building stage in the non-defecting group than in the defecting group, and that this activation decreased between stages as the relationship developed. Additionally, in this group the SA was activated while making trusting decisions, and this activation was the highest in pairs that exhibited the most trust and reciprocity (responding to a cooperative choice with a cooperative choice). In contrast, it was found that the ventral tegmental area (VTA) in the defecting group was activated while making trusting decisions, and that this activation was inversely proportional to the frequency with which a pair trusted and reciprocated one another.

The authors of this paper interpret their results as corroborating previous research on the function of these three brain regions. They suggest that the SA, which has been shown to facilitate social bonding by indirectly stimulating the release of oxytocin and vasopressin (Landgraf et al., 1995; Ophir et al., 2009), was recruited to form and maintain trusting relationships. The PcC is a region critical for building internal representations of others by inferring their intentions, cognitions, and emotional states (McCabe et al., 2001; Amodio and Frith, 2006), and so seems to have been activated as participants attempted to gauge the likelihood of their partners reciprocating trusting behaviors, and was thus critical in building up a reciprocal relationship. The ability provided by the PcC to "put oneself in another's shoes" is a unique aspect of human cooperation, and in itself recruits a complex network of neural systems, including visual processes in the occipital lobe (apparently for visualizing others' states) and various

prefrontal areas (McCabe et al., 2001). The VTA is a central component in the brain's dopaminergic rewards signaling pathway, which is the basis for reward-based learning and is known to be involved in making predictions concerning situational outcomes (Fiorillo, Tobler, and Schultz, 2003). Therefore, its activation in the defection group is likely a correlate of these participants' utilization of reward-motivated strategies rather than cooperation-motivated strategies, and of these individuals' anticipation of earning rewards as a result of their strategies (Krueger et al., 2007). This idea is supported by neuroimaging studies showing that prefrontal regions may downregulate rewards pathway activity in subjects who cooperate more (McCabe et al., 2001).

Virtual interaction and video-communications systems

In addition to studying the social and behavioral phenomena so far described, it is the aim of the current study to elucidate the impact of virtual interaction technologies on these processes. The Internet continues to be an extraordinary force for expanding and developing communications systems, and while a fair amount of research has been done on the now-aging innovations of Internet-based communication in the 1990s, for example chat rooms and other text-based interactions (Bargh, McKenna and Fitzsimons, 2002; Spears et al., 2002), research has struggled to keep up with the rapid development of emerging interaction modes—videoconferencing programs, new devices such as tablets and smart phones, and the ever-evolving social networking sphere. Of central importance to the current study is videoconferencing interactions. To give an idea of the scarcity of research in this area, a search of the journal database PsychINFO for "Skype," one of the leading videoconferencing computer programs on the market with 560 million users (Brockmann, 2010), yielded a total of 10 articles at the time of writing—most of which were concerned with experimental educational interventions, especially language-learning programs. Despite its underwhelming volume, a survey of what material there is on Internet, and video-based social interaction research at least gives us some background as to how researchers have regarded these fields in the past.

One longstanding debate has been in regard to whether or not all kinds of Internet-based communication are somehow less social or fulfilling than live interactions. In academic circles, the perception of the Internet as a negative social influence was fueled by a 1995 survey of new Internet users who reported an increase in depressive symptoms and a decrease in social involvement over their first 12-18 months of usage (Kraut et al., 1998). This surprised researchers, as the consumers in this

study used the Internet predominantly for communication, which is generally regarded as increasing feelings of well-being, connectedness and social involvement (Cohen and Wills, 1985). Trepidation about Internet use continued until several studies were published showing that Internet-aided social interactions actually tended to help individuals express themselves more freely (Bargh, McKenna, and Fitzsimons, 2002), increase social responsiveness (Spears et al., 2002), and interact in new ways (Tyler, 2002). In fact, a subsequent paper by the authors of the original anti-Internet survey described a new study which found longitudinal increases in social and community involvement and decreases in loneliness in some of its subjects (Kraut et al., 2002). It is worth noting, however, that these improvements were correlated with the participants' interaction style, with the most extroverted participants reaping the benefits of Internet use, while the most introverted reported no benefits, or even declines in social support and involvement. In this paper the researchers also discuss a follow-up study checking on the participants from the 1995 survey. Here, they found that the initially observed negative attributes were either no longer associated with Internet use in their sample, or had significantly declined since the previous survey.

Findings from traditional social interaction research also inform the current study. For example, it is known from collaboration studies that nonverbal cues, such as facial expressions and body language, can modulate situational outcomes and perceptions (Barron, 2000). Thus, we might expect that a task carried out via video interaction could elicit identical results compared to what we would expect if the task was carried out live, because video would still provide all or most of those visual cues. On the other hand, many studies have shown that putative human pheromones and other odorants can modulate social perceptions and interactions (Pierce, Cohen, and Ulrich, 2004; Olsson et al., 2006; Kline, Schwartz, and Dikman, 2007). These effects clearly would be inoperable in a video interaction context, and therefore unable to modulate the interaction. This could lead to different results from the same task being performed in two otherwise similar contexts.

Other aspects of "telepresence," the facsimile of social presence by which video-communications platforms attempt to provide the impression of shared space between users (Suwita et al., 1997), present challenges to the current study. Given that any video rendering will yield some reduction in visual resolution or quality as compared to natural human vision, some investigators have examined whether video degradation affects cooperative abilities (Guastavino et al., 2006). These researchers had volunteers attempt to complete creative spatial tasks (origami paper folding and Lego® brick building) using a videoconferencing setup where one individual instructed another using the video interlink. In the process of transmitting the video signal between each computer, the visual signal was compressed using

a variety of codecs, and consequently its quality was degraded. Intriguingly, the scientists found that while performance on the cooperative task was largely robust to moderate video degradation, performance on different tasks were sensitive to different varieties of degradation. For example, participants in the origami task required more time to complete the task when spatial resolution was degraded as a result of video compression, while the brick-building participants performed more poorly when the color depth of the video feed was reduced. These results suggest that a single ideal video compression protocol that could be usable across a variety of cooperative video-based tasks does not exist; rather, individual compression algorithms are better suited to some tasks than others. It is unknown whether video quality will affect the outcome of the current experiment, as its sensory entrainment components are largely audio- and movement-based, as opposed to the color- and resolution-based tasks used in the experiment described above. It is also possible that audio degradations kind could impact our results, as volunteers in our experiment will have to rely heavily on auditory cues.

Other researchers have focused on the more subtle issue of proximity. In face-to-face interactions, the distance between two conversants has previously been show to affect the individuals' impressions of one another, with conversations taking place in close proximity leading to the perception of persuasiveness and friendliness (Patterson, 1968; Mehrabian and Williams, 1969). Scientists examining the role of proximity in video-communications found that participants in a video-based conversation were less formal and more interactive when the perceived distance between the individuals was lessened (Grayson and Coventry, 1998). This effect parallels the dynamics of live interactions, but with a lesser magnitude. The researchers speculate that their results are the consequence of an unconscious increased perception of familiarity between the participants, as conversations between well-acquainted individuals tend to take place at similarly short distances. It is unknown whether proximity will affect the results of the current experiment, as to our knowledge there has been no research done on the effect of proximity on cooperation or rhythmic abilities. However, since in a virtual context proximity affects familiarity, which is at least tangentially related to trust and cooperation, it seems plausible that the proxemic element of telepresence in our experiment may have some bearing on our results.

Hypothesis

It is the aim of the current study to fill two gaps in the literature reviewed above. First, the effect

of rhythmic entrainment on cooperation and trust will be studied using a dyadic clapping task. Our hypothesis is that participants who clap in synchrony with one another will be more likely to cooperate in a subsequent Prisoner's Dilemma game and report higher levels of trust in a questionnaire. Secondly, we will study how a virtual, video-based interaction environment modulates the effect of rhythmic entrainment on cooperation and trust by repeating the first experiment, but separating the participants into two different rooms and having them complete the task via a webcam and microphone. Though the literature does not provide firm ground for a guess as to the outcome of this experiment, we tentatively hypothesize that participants in the synchronized group will exhibit increases in cooperation and trust over both the asynchronous video-based group and both of the live condition groups, as a result of the increased attentional demands required of this more novel task. Though this hypothesis represents one possible difference in outcomes between the live and virtual interaction environments, namely that the video environment will facilitate more trusting and cooperative behavior, two alternative outcomes are possible. Either the video interaction condition could lessen trust and/or cooperation, perhaps as the result of the degraded visual or audio quality of that environment, or it could have no effect on the dependent variables, indicating a lack of significant differences between the two conditions in their impact on cooperative behavior.

METHODS

Participants

72 undergraduates were recruited from introductory psychology and statistics courses at the College of Wooster. The students voluntarily signed up for the experiment using an online system (Sona Systems), and participation earned them course credit. Though the experiment tested students in pairs, the on-line description of the experiment discouraged students from participating with someone they knew. None of the participants were under the age of 18, and the local ethics committee approved the study.

Conditions and experimental design

The study featured a 2x2 statistical design, with two independent variables: task type (synchronous vs. asynchronous), and interaction type (live vs. virtual). 18 subjects (9 pairs) participated in each of the four possible combinations of variables: synchronous/live, asynchronous/live, synchronous/virtual and asynchronous/virtual. Statistical analyses were thus performed on between-groups differences in performance on post-task measures of trust and cooperation (see below).

The asynchronous task consisted of both subjects in each pair simultaneously clapping to a metronome being played through headphones. The metronome was played at slightly differing tempi for each subject such that the participants were forced to clap in asynchrony with one another. The tempi were 113 beats per minute (BPM) and 87 BPM (or approximately 1.88 Hz and 1.45 Hz). These tempi were somewhat arbitrarily chosen, but were selected to be different enough to discourage the participants from "drifting" into unison, while maintaining an equal offset from the tempo used in the synchronous condition. The metronome was played for 75 sec, and the participants were instructed to synchronize to their respective beats whenever they heard the beat.

In the synchronous condition, pairs clapped in unison. At the beginning of the task, the participants synchronized their claps to a metronome set at 100 BPM (1.67 Hz) being played through the same headphones that were used in the asynchronous task. College-aged groups have previously been shown to have little difficulty synchronizing finger-tapping to such moderate tempi (Thaut, Rathbun,

and Miller, 1997). After allowing 15 sec for the subjects to adjust to the tempo, the metronome was turned off and the students subsequently had to rely on one another to maintain an approximately constant tempo, with no external reference cues. After a further 60 sec, the experimenter instructed the subjects to stop clapping. This period of time was chosen to approximate the amount of time subjects spent producing rhythms in previous rhythmic processing studies (Thaut, Rathbun and Miller, 1997) and participating in musical tasks in music-modulated cooperation experiments (Wiltermuth and Heath, 2010). Although some of the literature in the latter category employed longer musical tasks of up to an hour (Anshel and Kipper, 1988), in light of the more recent studies that found significant results with much reduced time requirements of just a few minutes, a rhythmic task of an extended length was deemed unnecessary for the current experiment.

Pairs of subjects participating in the virtual conditions were seated in two separate rooms in front of a computer (Gateway E Series). Each room contained a webcam and a microphone, which were both connected to the computer in the opposite room. Each computer had a webcam video program open and the microphone input set to play through the headphones so, when seated in front of LCD monitors in each room, the subjects could see the other participant on the screen and hear them through headphones. Subjects then had to complete either the synchronous or asynchronous task in this environment. This slightly cumbersome cross-wired setup was necessary to foster a situation in which audio latency was minimized enough for the participants to be able to actually clap in unison in the synchronous condition. In the asynchronous condition, a recording of one of the two metronomes played through one participant's headphones, while the other metronome played in the headphones of their partner. In the synchronous condition, the metronome was played through small speakers in each room which were connected to the experimenter's computer in an adjoining room. Instructions such as "please stop clapping" were given by the experimenter through a microphone which sounded through the speakers.

In the live interaction condition, each pair completed the tasks together in a single room while seated in two chairs facing one another, with no obstruction between them. In the asynchronous condition, each wore headphones connected to a different computer playing one or the other of the asynchronous tempi. In the synchronous condition, both the participants' headphones were connected to a single computer playing the 100 BPM stimulus.

Dependent variables

Three dependent variables were measured: trust, perception of partner's trust and cooperation. After completing the rhythmic task, each subject completed first a trustworthiness questionnaire, then a cooperation game, the Prisoner's Dilemma (PD) (appendix A, fig. A. 1 and 2). The questionnaire, which was adapted from a previous synchronization study (Wiltermuth and Heath, 2010), asked the volunteers to answer two questions on a 7-point Likert scale: "How much do you trust the other participant?", and "How much do you think the other participant trusts you?" On this questionnaire participants also recorded their gender, whether or not they knew the other participant, and their email address (in order to receive the post-experimental debrief).

The classic PD has been described in-depth elsewhere (Flood, 1958; Axelrod, 1980a, 1980b). It involves a series of rounds in which each player has the opportunity earn points by selecting one of two arbitrary options; in the current study these were "red" and "blue." If both players select blue, each earns 3 points. If both select red, they each earn 1 point. If one player chooses red while the other chooses blue, the player choosing red earns 5 points and the player choosing blue earns 0 points. Thus, choosing blue is a cooperative act, because it is in the pair's overall best interest to select blue all the time, as this strategy earns the most points total between the two players. However, red is considered to be an act of defection, as an uncooperative or selfish player might opt to select red from time to time to maximize their personal gain. Alternately, a suspicious player might favor selecting red to avoid earning no points or to thwart the other player from earning extra points, should they decide to defect. At the conclusion of each round, the experimenter announced the choice each party had made. Thus, the participants could monitor both the number of points they earned, as well as have the opportunity to plan their subsequent moves as a reaction to the other player's previous actions. The ratio of the number of blue choices to red choices that a player made was used to measure propensity for cooperation with the opponent (Wolf et al., 2009). Our version was adapted from a musical cooperation study (Anshel and Kipper, 1988) and featured 10 rounds. Repeated rounds were necessary, as previous studies have shown that single-round versions of the PD elicit abnormally high cooperation levels when played by individuals (Simpson, 2004). Before the game began, participants were informed that they would receive a reward proportional to the amount of points they earned. At the conclusion of the experiment, participants were allowed a piece of candy for every three points accumulated during the game.

The questionnaire and the PD were completed in a single room containing both subjects for both the live and virtual conditions. This was the same room as was used for the rhythmic task in the live conditions. Participants completed the questionnaire and PD seated across a table from one another with a plastic divider erected between them, so neither person could see the other's answers but could see

their face. The experimenter stood to the side of the participants, so he could see both their answers and announce them when appropriate during the PD.

A third dependent variable was measured for screening purposes. After completing the tasks just described, participants were recorded using digital audio recording and editing software (Audacity) while clapping in synchrony with a 100 BPM (1.67 Hz) metronome for approximately 50 sec. These samples were cropped to the 30 sec period between the 10th and 40th seconds of the recording, so exactly 50 beats could be analyzed for each subject. The first and last 10 sec of each recording was cut out so as to allow for the initial adjustment to the beat when the metronome started, as well as the mild clapping fatigue that many participants displayed toward the end of these clapping periods. Similar methods have been applied to the analysis of rhythmic audio samples in previous studies (Thaut, Rathbun, and Miller, 1997). Software was used to amplify each clap as needed and to produce time markings for each clap, from which SE and IRI was then calculated (appendix B, fig. B. 1, 2 and 3). In the uncommon cases where claps were too quiet to hear or too indistinct to amplify, those data points were omitted and analysis was performed on the remaining beats. The purpose of taking these measurements was to identify individuals incapable of properly executing the clapping tasks so they could be excluded from statistical analysis. Individuals were excluded from analysis if their SE or IRI error (difference between ISI and IRI) exceeded two standard deviations from the mean.

RESULTS

Since none of the participants exceeded two standard deviations from the average SE and IRI, all were included in the statistical analyses. Neither of these screening variables was found to be associated with any other dependent variables. However, because an ANOVA showed that the volunteers who reported knowing their partner prior to the experiment demonstrated significantly higher self-reported trust scores—trust of other, $F(1,71)=11.84$, $p=0.001$, and perception of other's trust, $F(1,71)=13.55$, $p<0.001$—these volunteers ($N=11$) were excluded from analysis, leaving a sample size of $N=61$ with a roughly equal number of participants in each condition.

A two-way ANOVA revealed that participants in the synchronous conditions believed their partners trusted them more than did those in the asynchronous conditions, $F(1,57)=4.87$, $p=0.031$ (fig. 1). Additionally, the trust that participants reported having in their partners differed between the interaction types in a marginally significant manner, with participants in the virtual conditions reporting more trust in their partners than those in the live conditions, $F(1,57)=3.76$, $p=0.057$ (fig. 2). No significant differences were found between any of the groups for cooperation or defection levels, and no significant interactions were observed. Though gender differences were not a primary concern of the present study, an ANOVA found no significant differences between the answers of males and females.
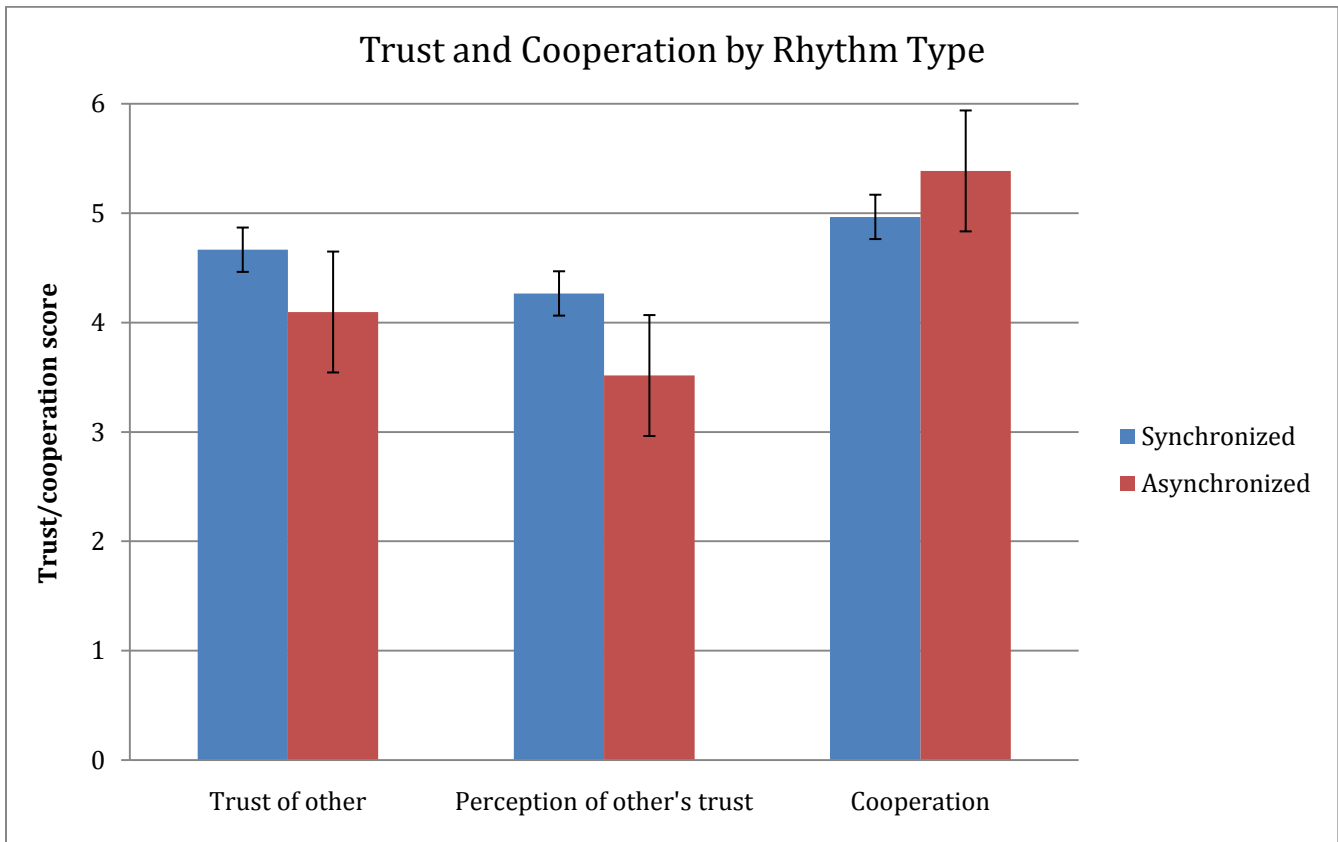
Figure 1. Trust and cooperation scores gathered from the surveys and PD after participating in either the synchronous (*N*=30) or asynchronous (*N*=31) clapping tasks. Participants in the synchronous groups believed their partners trusted them more than the participants in the asynchronous groups. The cooperation variable displayed no significant differences between the rhythmic groups, $F(1,57)=0.451$, $p=0.50$, and individuals did not report differing amounts of trust in their partners, $F(1,57)=3.392$, $p=0.07$. Bars represent the standard error.
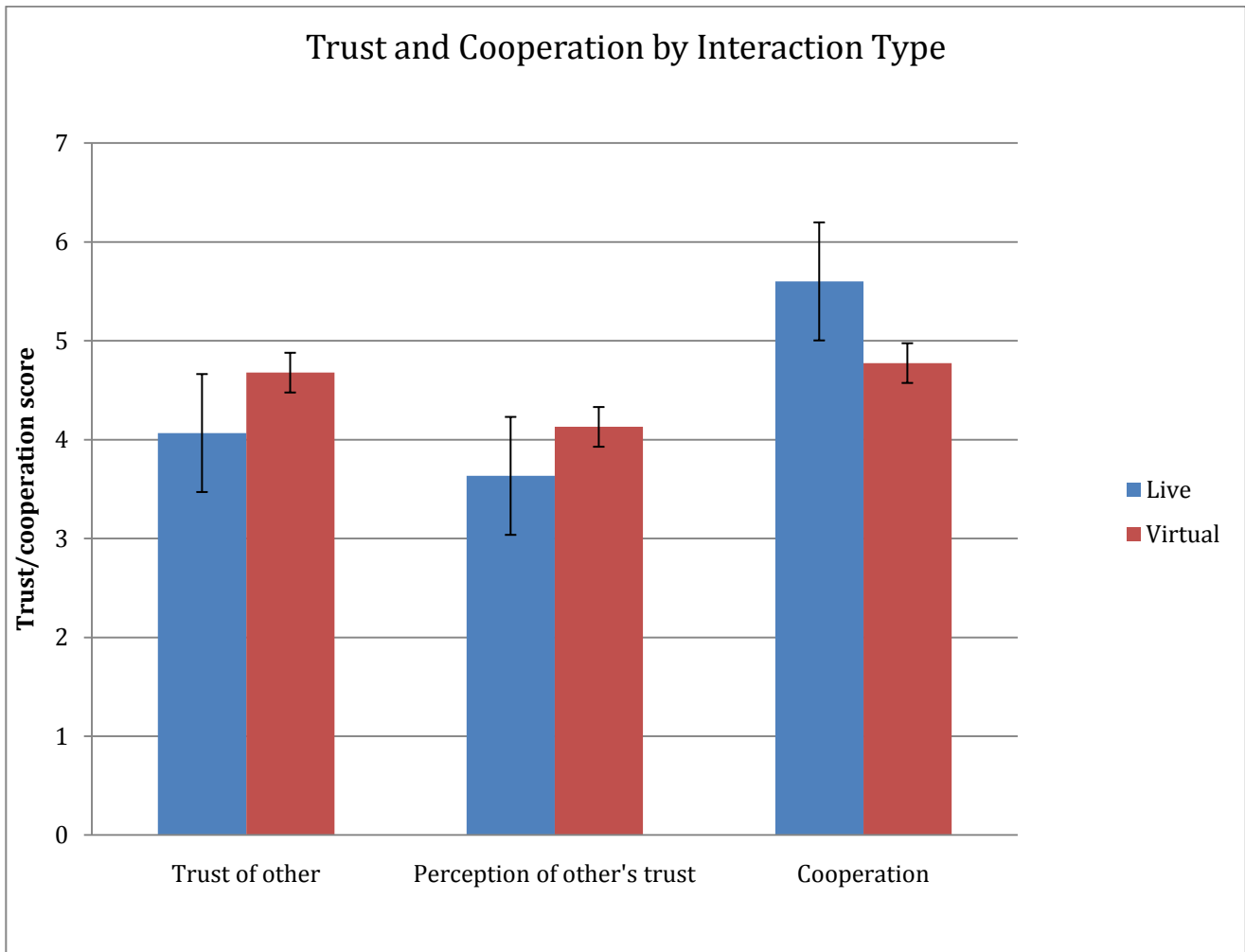
Figure 2. Trust and cooperation scores as measured by survey responses and PD decisions after participating in either the live (N=30) or virtual (N=31) conditions of the experiment. While the extent to which participants trusted their partners reached marginal significance, neither the perception of their partner's reciprocal trust nor their cooperation levels reached significance, $F_{(1,57)}=2.417$, $p=0.126$ and $F_{(1,57)}=1.387$, $p=0.244$ respectively. Bars represent the standard error.

DISCUSSION

The purpose of the current study was to examine whether cooperation and trust would be altered as a result of participation in a synchronous or asynchronous clapping task carried out in either a face-to-face ("live") or a virtual environment. We hypothesized that cooperation and trust would be facilitated by the synchronous clapping tasks, as had been shown in previous research, and by the virtual environment. This hypothesis was partially supported by our experiment, in that the participants perceived their partners as significantly more trusting after completing the synchronous task, as compared to those that participated in the asynchronous task. Likewise, as hypothesized, self-reported trust showed a marginally significant increase for those in the virtual interaction groups as compared to the live groups. None of our cooperation hypotheses were supported by our results, as no differences were found between any of the groups with regard to this variable.

The trend toward an increase in self-reported trust in the virtual groups is a finding with potentially fascinating implications. We believe that this variable only reached the edge of significance due to the relatively modest size of our study, and that a larger study with more stringent controls on the virtual interaction environment could possibly see this trend become significant. If the phenomenon is confirmed, we see two likely explanations for it. Either something about the physical details of the interaction medium influences the participants' proclivity towards trust, or there is a social effect at work.

Let us first explore the former explanation. The inherent compression and consequential degradation of video and audio quality caused by any video-communications platform almost guarantees altering the social experience of the technology's users in some way. Perhaps the most basic degradation of sensory input is the loss of one dimension in transmitting visual data from the real world to a computer monitor. Research has shown that this factor alone is responsible for some of the loss of social presence provided by video-communications technology as opposed to live interactions. In one study, participants using a three dimensional video-communications system reported a greater impression of life-like interaction and significantly higher levels of enjoyment of the technology compared to a group utilizing a standard two dimensional interface. Additionally, this study showed that a disparity between where the camera is located and where a participant is gazing, resulting in indirect eye contact, further disrupts the quality of the social interaction (Mülbach, Böcker and Prussog, 1995). Previous research has also revealed that the perceived amount of distance between two users of a video-communications device can significantly impact such socio-communicative variables as conversational turn taking and

perceived persuasiveness (Grayson and Coventry, 1998).

All of these caveats presented a certain amount of variability in the current study. We utilized standard computer monitors and webcams, so each participant's video-feed was presented in two dimensions. As is the case with most modern video-communications technology, the webcams used by the participants were perched atop their monitors, so any eye contact made during the experiment was indirect. (It is worth noting that the majority of the participants in the live conditions actively avoided one another's gaze while clapping, and we find it likely that this behavior persisted in the virtual conditions. This potentially makes any discussion of the consequences of the subtleties of eye contact a moot point, as the dyads probably had none.) Finally, the volunteers in our experiment were sequestered into two windowless rooms for the clapping portion of the study, with the experimenter in a third room. Thus, participants were allowed to adjust their chairs, and consequently their distance from the webcams, to their own liking and without the experimenter taking note. It is possible that any or all of these variables could have impacted the current study, and been responsible for the trend towards increased trust in the virtual conditions. It is essential that future research isolates or controls for these variables to avoid ambiguous results.

The other possibility in explaining the virtual groups' increased trust is that a social effect is at work. Due to the technological constraints just outlined, attempting joint behavior (synchronized or otherwise) remotely via a video-communications system has inherent pitfalls that complicate even simple tasks, despite low transmission latencies. Audio and visual degradation, indirect eye contact, incomplete visual cues, and reduced expressiveness of body language are but a few of the challenges faced by the participants in the virtual conditions. It is likely that overcoming these challenges for a common goal could facilitate a trusting relationship between the participants. A well-characterized phenomenon in the social psychology literature is in-group bias, where people who are grouped together by some arbitrary rubric tend to act more cooperatively or think more positively of others in the group (Brewer and Silver, 1978). This idea bears some similarities to the current situation—our participants may have felt "grouped together" as a result of the unique nature of their task, and developed in-group biases in favor of one another as a consequence. Likewise, one study on music-induced trust manipulated "group fate" and "group identity," two concepts similar to in-group bias, in a nonmusical comparison group. While the researchers found their musical groups to be more trusting than these comparison groups, the paper implies that these groups also experienced a boost in trust (Wiltermuth and Heath, 2009).

The lack of any significant findings related to the cooperation variable is unexpected, considering

that the three studies that the current experiment is methodologically modeled after found cooperation increases in experimental groups with similar characteristics to our own (as in our study, none of these experiments studied veteran musicians) (Anshel and Kipper, 1988; Wiltermuth and Heath, 2009; Kirschner and Tomasello, 2010). Since the primary difference between these three experiments and the current study is that our tasks involved only rhythm, with no melodic entities whatsoever, this finding suggests that there is some aspect of melody (or perhaps harmony) in and of itself that leads joint music-makers to act more cooperatively. If confirmed in future studies, the finding of specific disparities between the psychological effects of rhythm versus music opens up exciting new research questions.

It should also be noted that it is possible that we found no significant differences in our cooperation variable as a result of the unique PD setup we utilized. Whereas in previous studies the PD has involved "training" or "practice" rounds before the actual testing begins, in our experiment, participants played only ten round in total, which were subsequently used for statistical analysis. Thus, there is a chance that our participants did not have enough exposure to the game to effectively grasp its mechanisms and strategies and as a result, the game may not have been accurately recording their cooperativeness. In our opinion, though, the game is intuitive enough that this should not have been a mitigating factor. Additionally, it is probable that a more naïve approach to the game actually increases its accuracy in measuring implicit cooperative tendencies, since it forces the players to rely more on subconscious motivators.

The finding that rhythmic synchrony boosted our participants' perception of their partner's trust in them offers support for the idea that purely rhythmic synchrony facilitates trusting relationships, just as previous researchers have found a link between musical synchronicity and trust (Wiltermuth and Heath, 2009; Anshel and Kipper, 1988). This finding is important because while previous research has always utilized melody and sometimes harmony and dance-like movement (Kirschner and Tomasello, 2010) in addition to rhythm in assessing the relationship between trust and musical interaction, ours was the first study to focus exclusively on the rhythmic element. As rhythm was necessarily present in the musical activities used in the aforementioned studies, our results hint that it may be the precipitating factor in facilitating trust in these situations. Further research is needed to tease out whether or not this is the case—it is possible that all or some of the various substructures of music are trust-facilitating. Future studies should attempt to isolate the harmonic and melodic musical infrastructures to evaluate whether these components individually contribute a trust and/or cooperation boost in dyadic activities. Previous studies have shown that gender differences exist in melodic versus rhythmic processing during some noncooperative tasks (Crust, 2008), while other researchers are studying rhythmic and melodic aspects

of language acquisition (Speer and Ito, 2009), so there is no lack of unexplored territory which could potentially impact the field of music or rhythm-induced trust.

An interesting question that this finding raises is why synchrony only raised the volunteers' perception of how much their partners trusted them, and not their self-reported trust in their partner (though this variable was reaching the edge of marginal significance, the effect was not pronounced enough for us to confidently interpret it as being a real difference). It is possible that one or both of the trust variables did not reliably measure what we assumed it to measure. For example, a very self-confident participant being asked to respond to the question, "how much do you think the other participant trusts you?" might subconsciously respond with an inflated response, while a very humble individual might record an unusually low score to avoid seeming arrogant. Was this the case, the variable would be measuring what the respondent wanted to appear to feel, and not what they actually feel.

However, assuming that the trust questionnaire accurately measured the participants' trust, the increases in perceived trust can be explained by hypothesizing that the synchronous rhythmic tasks selectively activated cognitive-neural responses associated with perceiving trust in others, more so than just stimulating trusting behavior in general. Neuroanatomically this is possible—as described in the introduction, the paracingulate cortex (PcC) is a brain region responsible for building cognitive representations of other individual's thoughts and emotions. Its proximity to the complex prefrontal networks activated by entrainment opens the possibility that stimulation of the entrainment networks could incidentally activate the nearby PcC, thereby producing the observed boost in the perception of trust variable. In fact, close proximity between these structures is not necessarily required for this cross-stimulation, if the oscillating synchronization network model that some scientists use to explain the mechanics of neurological entrainment holds true (Buonomano and Merzenich, 1995; Thaut, 2003). Provided PcC networks were tuned to the proper physiological resonance, entrainment networks could activate the perception of trust nonlocally via oscillator coupling. These explanations remain speculative for the time being, but should be empirically scrutinized in future research.

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REFERENCES

Amodio DM, Frith CD (2006) Meeting of the minds: The medial frontal cortex and social cognition. Nat Rev Neurosci 7:268-277.

Anshel A, Kipper DA (1988) The influence of group singing on trust and cooperation. J Music Ther 25:145-155.

Axelrod R (1980) Effective choice in the Prisoner's Dilemma. J Conflict Resolut 24:3-25.

Axelrod R (1980) More effective choice in the Prisoner's Dilemma. J Conflict Resolut 24:379-403.

Balter M (2010) Did working memory spark creative culture? Sci Mag 328:160-163.

Bargh JA, McKenna KY, Fitzsimons GM (2002) Can you see the real me? Activation and expression of the "true self" on the Internet. J Soc Issues 58:33-48.

Barron B (2000) Achieving coordination in collaborative problem-solving groups. J Learn Sci 9:403-436.

Bernieri FJ (1988) Coordinated movement and rapport in teacher-student interactions. J Nonverbal Behav 12:120-138.

Bernieri FJ, Reznick JS, Rosenthal R (1988) Synchrony, pseudosynchrony, and dissychrony: Measuring the entrainment process in mother-infant interactions. J Pers Soc Psychol 54:243-253.

Brewer MB, Silver M (1978) Ingroup bias as a function of task characteristics. Eur J Soc Psychol 8:393-400.

Brockmann, P (2010) Skype statistics 1H2010. Brockmann & Company. Retrieved from http://www.brockmann.com/communications/voip/2112-skype-statistics-1h2010

Buonomano DV, Merzenich MM (1995) Temporal information transferred into a spatial code by a neural network with realistic properties. Science 267:1028-1030.

Cohen S, Wills TA (1985) Stress, social support, and the buffering hypothesis. Psychol Bull 98:310-357.

Crust L (2008) Perceived importance of components of asynchronous music during circuit training. J Sport Sci 26:1547-1555.

Darwin C (1891) The descent of man and selection in relation to sex. New York, NY: D. Appleton and Company.

Darwin C (1909) Foundations of the origin of species: Two essays written in 1842 and 1844. (Darwin F, Ed). London, UK: Cambridge University Press.

Eek D, Gärling T (2006) Prosocials prefer equal outcomes to maximizing joint outcomes. Brit J Soc Psychol 45:321-337.

Filipic S, Tillmann B, Bigand E (2010) Judging familiarity and emotion from very brief musical excerpts. Pyschon B Rev 17:335-341.

Fiorillo CD, Tobler PN, Schultz W (2003) Discrete coding of reward probability and uncertainty by dopamine neurons. Science 299:1898-1902.

Flood MM (1958) Some experimental games. Manage Sci 5:5-26.

Graham R, Robinson J, Mulhall P (2009) Effects of concurrent music listening on emotional processing. Psychol Music 37:485-493.

Grayson D and Coventry L (1998) The effects of visual proxemic information in video mediated communication. SIGCHI Bull 30:30-39.

Groussard M, Rauchs G, Landeau B, Viader F, Desgranges B, Eustache F, Platel H (2010) The neural substrates of musical memory revealed by fMRI and two semantic tasks. Neuroimage 43:1301-1309.

Gustavino C, Levitin DJ, Spackman S, Chan-You A, Cooperstock JR (2006) Quantifying the perceptual effects of videoconferencing compression. J Am Soc Inf Sci Tec (Submitted).

Jäncke L (2009) The plastic human brain. Restor Neurol Neuros 27:521-538.

Jantzen KJ, Steinberg FL, Kelso JA (2005) Functional MRI reveals the existence of modality and coordination-dependent timing networks. Neuroimage 25:1031-1042.

Kirschner S, Tomasello M (2010) Joint music making promotes prosocial behavior in 4-year-old children. Evol Hum Behav 31:354-364.

Kline JP, Schwartz GE, Dikman ZV (2007) Interpersonal defensiveness and diminished perceptual acuity for the odor of a putative pheromone: Androstenone. J Biol Psychol 74:405-413.

Koelsch S (2010) Towards a neural basis of music evoked emotions. Trends Cogn Sci 14:131-137.

Kraut R, Kiesler S, Boneva B, Cummings J, Helgeson V, Crawford A (2002) Internet paradox revisited. J Soc Issues 58:49-74.

Kraut R, Patterson M, Lundmark V, Kiesler S, Mukopadhyay T, Scherlis W (1998) Internet paradox. Am Psychol 53:1017-1031.

Krueger F, McCabe K, Moll J, Kriegeskorte N, Zahn R, Strenziok M, Heinecke A, Grafman J (2007) Neural correlates of trust. P Natl Acad Sci USA 104:20084-20089.

Landgraf R, Gerstberger R, Montkowski A, Probst JC, Wotjak CT, Holsboer F, Engelmann M (1995) V1 vasopressin receptor antisense oligodeoxynucleotide into septum reduces vasopressin binding, social discrimination abilities, and anxiety related behavior in rats. J Neurosci 15:4250-4258.

Lebrun-Guillaud G, Tillmann B, Justus T (2008) Perception of tonal and temporal structures in chord sequences by patients with cerebellar damage. Music Percept 25:271-283.

Levitin D (2006) This is your brain on music: The science of a human obsession. New York, NY: Penguin Books.

McCabe K, Houser D, Ryan L, Smith V, Trouard T (2001) A functional imaging study of cooperation in two-person reciprocal exchange. P Natl Acad Sci USA 98:11832-11835.

Molinari M, Leggio MG, Thaut MH (2007) The cerebellum and neural networks for rhythmic sensorimotor synchronization in the human brain. Cerebellum 6:18-23.

Mülbach L, Böcker M, Prussog A (1995) Telepresence in video-communications: A study on stereoscopy and individual eye contact. Hum Fact 37:290-305.

Olsson MJ, Lundstrom JN, Diamantopoulou S, Esteves F (2006) A putative female pheromone affects mood in men differently depending on social context. Eur Rev Appl Psychol 56:279-284.

Ophir AG, Zheng D, Eans S, Phelps SM (2009) Social investigation in a memory task relates to natural

variation in septal expression of oxytocin receptor and vasopressin receptor. Behav Neurosci 123:979-991.

Overy K, Turner R (2009) The rhythmic brain. Cortex 45:1-3

Pinker S (1997) How the mind works. London, UK: W.W. Norton & Company.

Renoult L, Roux S, Riehle A (2006) Time is a rubberband: Neuronal activity in monkey motor cortex in relation to time estimation. Eur J Neurosci 23:3098-3108.

Roberts S, Eykholt R, Thuat MH (2000) Analysis of correlations and search for evidence of deterministic chaos in rhythmic motor control. Phys Rev E 62:2597-2607.

Simpson B (2004) Social values, subjective transformation, and cooperation in social dilemmas. Soc Psychol Quart 67:385-395.

Spears R, Postmes T, Lea M, Wolbert A (2002) When are net effects gross products? The power of influence and the influence of poser in computer-mediated communication. J Soc Issues 58:91-107.

Speer SR, Ito K (2009) Prosody in first language acquisition: Acquiring intonation as a tool to organize information in conversation. Lang Linguist Compass 3:90-110.

Sugimoto T, Kobayashi H, Nobuyoshi N, Kiriyama Y, Takeshita H, Nakamura T, Hashiya K (2010) Preference for consonant music over dissonant music by an infant chimpanzee. Primates 51:7-12.

Suwita A, Bocker M, Muhlbach L, Runde D (1997) Overcoming human factors deficiencies of video-communications systems by means of advanced image technologies. Displays 17: 75-88.

Tecchio F, Salustri C, Thaut MH, Paqualetti P, Rossini PM (2000) Conscious and preconscious adaptation to rhythmic auditory stimuli: a magnetoencephalographic study of human brain responses. Exp Brain Res 135:222-230.

Thaut MH (2003) Neural basis of rhythmic timing networks in the human brain. Ann N.Y. Acad Sci 999:364-373.

Thaut MH (2005) Rhythm, music and the brain. New York, NY: Routledge.

Thaut M, Rathbun J, Miller R (1997) Music versus metronome timekeeper in a rhythmic motor task. Int J Arts Med 5:4-12.

Thaut MH, Miller RA, Schauer LM (1998) Multiple synchronization strategies in rhythmic sensorimotor tasks: Phase vs period correction. Biol Cybern 79:241-250.

Thaut MH, Tian B, Azimi MR (1998) Rhythmic finger tapping to cosine-wave modulated metronome sequences: Evidence of subliminal entrainment. Hum Movement Sci 17:839-863.

Valdesolo P, Ouyang J, DeSteno D (2010) The rhythm of joint action: Sychrony promotes cooperative ability. J Exp Soc Psychol 46:693-695.

Wiltermuth S, Heath C (2010) Synchrony and cooperation. Psychol Sci 20:1-5.

Wolf ST, Cohen TR, Kirchner JL, Rea A, Montoya RW, Insko CA (2009) Reducing intergroup conflict through the consideration of future consequences. Eur J Soc Psychol 39:1250-1254.

APPENDIX A

Participant #___

1. Your gender is (circle one):   M   F

2. On a scale of 1 (not at all) to 7 (very much), how much do you trust the other participant? Please circle one of the following:

    not at all   1—2—3—4—5—6—7   very much

3. On a scale of 1 (not at all) to 7 (very much), how much do you think the other participant trusts you? Please circle one of the following:

    not at all   1—2—3—4—5—6—7   very much

4. Do you know the other person? Circle one of the following: Yes   No

5. Please write down your email address:_____

Figure A. 1. The trust survey used to produce scores for the dependent variables.

If both players choose blue, each earns 3 points.

If both players choose red, each earns 1 point.

If one player chooses red and the other chooses blue, the player that chose red earns 5 points, and the player that chose blue earns 0 points.

Round number	My choice		Other player's choice		Points I earned
1	Red	Blue	Red	Blue	
2	Red	Blue	Red	Blue	
3	Red	Blue	Red	Blue	
4	Red	Blue	Red	Blue	
5	Red	Blue	Red	Blue	
6	Red	Blue	Red	Blue	
7	Red	Blue	Red	Blue	
8	Red	Blue	Red	Blue	
9	Red	Blue	Red	Blue	
10	Red	Blue	Red	Blue	
TOTAL	--------------------------		--------------------------		

Figure A. 2. The matrix participants filled out while playing the PD game. Answers were analyzed as the cooperative dependent variable.
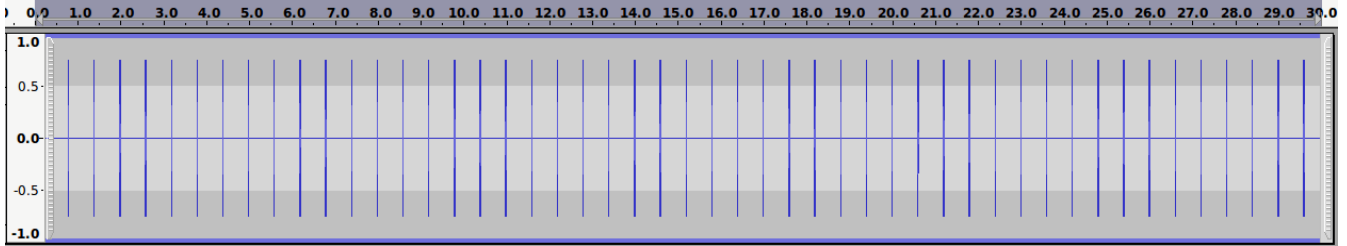
APPENDIX B

Figure B. 1. Waveform of the fifty metronome beats contained in each of the screening samples. X-axis is in seconds, y-axis is in logarithmic decibels. Though participants were originally given approximately 50 sec to clap, this was cropped to the middle 30 sec to allow for adjustment to the beat at the beginning and fatigue at the end.
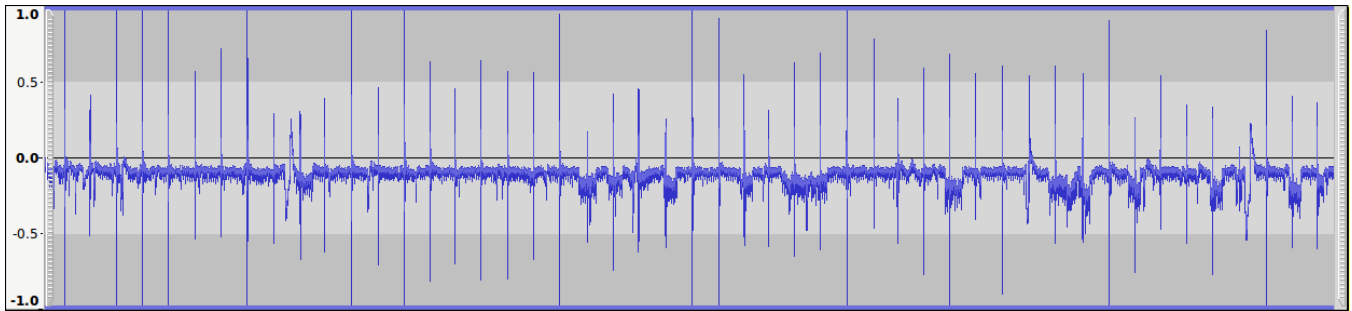

Figure B. 2. 30 sec long waveform of a participant clapping. As is the case with this particular example, the samples were usually amplified to allow the software to detect each clap (spikes) as separate from the background noise (dense coloring around the 0.0 mark). This figure is to scale with Fig. A. 1.
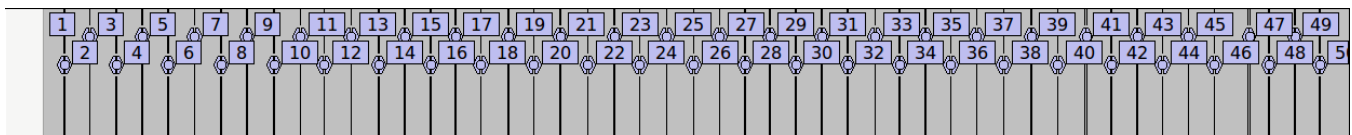

Figure B. 3. Labels marking each of the fifty claps in a 30 sec sample. These labels were subsequently exported as text demarcations of the peak of each clap which were then analyzed to find the SE and IRI.