

Does interpersonal liking lead to interpersonal synchrony in musical contexts?

Zachary J. Melton¹, Roger Chaffin², Kayleigh Kangas-Dick³,


Kerry L. Marsh² and Alexander P. Demos¹


¹University of Illinois at Chicago


²University of Connecticut

³Teachers College Columbia University

Author Note

Zachary J. Melton  <https://orcid.org/0000-0002-4534-9455>

Kerry L. Marsh  <https://orcid.org/0000-0001-5106-5419>

Alexander P. Demos  <https://orcid.org/0000-0001-7964-7808>

Correspondence concerning this article should be addressed to Zachary J. Melton and Alexander P. Demos, 1007 West Harrison Street, Chicago, IL, 60607. The corresponding authors can be reached at zmelto2@uic.edu and ademos@uic.edu.

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Abstract

The causal relationship of interpersonal liking affecting interpersonal synchrony is inconsistently documented. This study tests whether a) interpersonal liking increases both behavioral and perceived synchrony, and b) if people will synchronize with an agreeable partner over a competing musical stimulus. We had college students ($N = 25$) shake an egg-shaker with an agreeable or disagreeable confederate without music, with music, and with specific instruction to synchronize. Participants reported liking the agreeable confederate more than the disagreeable confederate and rated their relationship more positively, however both behavioral and perceived synchrony were unaffected by the agreeableness of the confederate. Thus, we failed to replicate previous findings in an auditory only context. Furthermore, participants who believed they were more synchronized with the confederate liked the confederate more and felt more like a team but the degree of behavioral synchrony was unrelated to these social perceptions. Perception of synchrony appears to be more important for social bonding than behavioral synchrony.

Keywords: interpersonal synchrony, music synchrony, recurrence quantification analysis, interpersonal liking, social bonding

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Engaging synchronously with another person increases positive feelings about both that person (Hove & Risen, 2009) and the self (Lumsden et al., 2014). Interpersonal synchrony also increases the extent to which people feel a sense of joint identity with a partner (e.g., “being on the same team;” Wiltermuth & Heath, 2009) and feelings of social connection (Lumsden et al., 2014), compassion (Valdesolo & DeSteno, 2011), and trust (Launay et al., 2013). Even outgroup members in minimal groups paradigms¹ who engage in synchronous activity are seen more positively than outgroup members who engaged in non-synchronous movements (Tunçgenç & Cohen, 2016).

Research has primarily focused on how behavioral synchrony affects peoples’ perceptions of others; however, less is known about whether manipulating perceptions of others—such as prosociality and liking—affects synchronizing with them, particularly in musical settings. There are a handful of studies that manipulate perceptions of others in visual contexts. Lumsden and colleagues (2012a) found participants synchronized their arm curls with a confederate more when primed to be more prosocial compared to when they were primed to be pro-individual². Miles and colleagues (2010) manipulated whether a confederate was late or not, finding that the synchrony of exercise steps between partner and confederate was higher for those with a partner who was on time compared to those with partner who was late³. The participant was situated behind the confederate so as to see their steps, while being unable to hear them. Similarly, Zhao et al. (2017) found that participants were able to spontaneously synchronize their finger tapping by watching and not hearing a friendly/polite confederate during

¹ Randomly assigns participants to groups as opposed to using existing group memberships (e.g., race, socio-economic status).

² Estimated effect size from reported M and SD , $d = .91$ ($N = 30$; Study 2).

³ Reported effect size on the interaction was $\eta_p^2 = .16$, or estimated $d = .87$ ($N = 26$).

the third of three trials. Further, when the confederate was distracted/rude, synchrony was significantly lower than synchrony with the friendly/polite confederate⁴. However, on the first trial, they found a significant decrease in synchrony from baseline and no differences between the friendly/polite and distracted/rude confederate. Thus, the evidence that liking affects synchrony in a visual context is limited.

People spontaneously move to music and synchronize with it (Dotov et al., 2021; Repp & Su, 2013; Toivainen et al., 2009), just as they spontaneously synchronize with other people's movements. Demos and colleagues (2012) showed that the more people spontaneously synchronized to music, the more they reported feeling connected to their partner. Further, music lowers overall interpersonal synchrony when music competes with visual information of a partner's movements. The current study will keep all information auditory to determine how liking a partner affects synchrony. Therefore, we designed this study where the music was a central aspect related to the liking of the partner and interpersonal synchrony occurred exclusively through auditory information. Participants were asked to choose music from a shortlist of song titles, but the music would be a novel song. The confederate was then randomly assigned to comment on the participant's selection in one of two ways: positively (agreeable) or negatively (disagreeable). Participants were then asked to shake an egg-shaker (maraca) without seeing the confederate where we examined both uninstructed (spontaneous) and instructed (intentional) synchronization with the confederate and a competing musical stimulus. If likability leads to synchrony, participants should synchronize with a likable confederate over a disagreeable confederate. We provided music as an alternative sound source with which participants could synchronize and it competed with the sound of the partner's movement. If the

⁴ Effect sizes cannot be inferred due the nature of the statistical reporting (linear mixed models without random coefficients reported).

confederate is agreeable, participants should synchronize more with the confederate and less with the music. If the confederate is disagreeable, participants should synchronize more with the music and less with the confederate.

Finally, most studies only focus on behavioral synchrony; however, less is known about the social cause of increased liking amongst partners. The current mechanism is believed to be direct: Synchrony itself increases feelings of liking (Savage et al., 2020). However, the cause could be more indirect, where the more someone *perceives* they synchronized, the more they like that partner. Macpherson and colleagues (2020), replicating Lumsden et al. (2012b), found that observers reported more perceived synchrony for partners with similar skin tones than for those with different skin tones, even when synchrony was objectively the same. Thus, perceived synchrony can be influenced by social information about the two partners, independent of actual, behavioral synchrony. We tested whether perceived synchrony is higher with an agreeable confederate than a disagreeable confederate.

Method

Participants

Undergraduate participants ($N = 25$; 72% female; mean age = 18.7, $SD = 0.80$) were partnered with a 20-year-old, Latinx confederate.

Materials and Procedure

Participants were told that the study tested a new system for measuring caloric expenditure on two people simultaneously to collect data more efficiently. The experimenter demonstrated how to hold the “maraca” (an egg-shaped plastic shell containing small beads) and a LIBERTY LATUS Polhemus motion sensor in the dominant hand and shake it at a steady rate of about 120 bpm.

Next, the participant and confederate each left the experimental room in turn, leaving the other to provide 45 seconds of baseline data by shaking the maraca alone, without a partner (*baseline condition*). When both partners had returned to the room, we manipulated the agreeability of the confederate by asking the participant to choose the music that both partners would listen to from a list of novel song titles created for the study. The experimenter then asked the confederate if the choice “sounds okay”, to which the confederate was randomly assigned to respond either, “Yeah, that sounds great!” (agreeable) or “No, not really, but whatever” (disagreeable). When saying these words, the nonverbal behavior of the confederate was upbeat and friendly in the former condition, and overtly hostile and cold in the latter condition. Regardless of which title the participant chose, the same song was played: a strong isochronous beat of 128 bpm techno-style piece created in Garage Band.

Next, we conducted three 45-second trials, one for each of the three instruction conditions, always in the same order. During this time, the participant and confederate stood on opposite sides of the room, separated by a curtain, through which the sounds of the maraca and the music were audible. The participant did not know that the confederate was wearing earphones (playing a 107-bpm metronome) covered by over-ear sound mufflers to that prevented her from hearing the participant’s sounds/music. Thus, the confederate moved at a different tempo from the music.

Spontaneous (Music On) Condition. The participant and confederate were instructed to “do what you did before [during the baseline trial],” and to start moving when the music began and finish when it ended.

Intentional Conditions. The participant and confederate were instructed to “try to move at the same rate as the other person”, first with music [*intentional (music on) condition*] and then without [*intentional (music off) condition*].

Finally, participants completed a questionnaire in which they rated the confederate for *likability* and their relationship with the confederate for *stress*, *awkwardness*, and *pleasantness*, using 7-point Likert scales, and feeling like a *team*, and *unconnected*, on 5-point scales. We administered the survey following the experimental manipulation to avoid disclosing the purpose of the manipulation. They also rated their *closeness* to the confederate by indicating which of seven pairs of circles, varying in amount of overlap, best described their relationship (Inclusion of Other in the Self Scale; Aron et al., 1992). Lastly, they indicated how much of the time they moved at the same pace as their partner (*perceived synchrony*), on a 5-point scale.

Measurement

Although participants heard 107 bpm (560.75 IOI) from the confederate and 128 BPM (468.75 IOI) from the music, they naturally generated sound at double those rates (280.4 IOI or 234.38 IOI, respectively) because the maraca makes a sound at both peaks and valleys. This was determined to be a comfortable rate through piloting. Visual inspection of the data revealed that movement on the Y-axis was not cleanly captured for some participants who did not follow instructions on how to hold the sensor. To fix this, we transformed and filtered the sensor data from both the participant and confederate. We differentiated the three degrees of freedom from the sensor (X, Y, Z) and took the Euclidian distance, applied a narrow band Butterworth filter between 12.5% above and below their peak movement rate (based on non-derivative-based peak picking), and reconstructed movements from these new peaks using a sine-wave transformation method previously employed (see Demos et al., 2018).

Motion Analysis

We calculated phase synchronization between partner and confederate (interpersonal synchrony) and partner and music (music synchrony) by means of recurrence (RQA; CRP toolbox; Marwan, 2021; Marwan et al., 2007). This metric calculates the recurrence quantification (i.e., when the person's egg-shaker repeats its pattern of movement) independently for the person and confederate. Then we correlated the amount of recurrence at all time lags up to a specific window size between the two signals of interest (e.g., egg-shaking between participant and confederate). A zero value represents a low similarity of movement in terms of their phase between the two sources and a 1 represents perfect overlap. This process was then repeated to capture musical synchronization by capturing the recurrence of the sinusoid representing the musical beat and comparing that signal to the partner's.

RQA parameters. The first and last second of each trial was removed before analysis to remove transience. Next we found the time-lag parameter by calculating the median value of the first minimum of the average mutual information index from both the baseline and intentional w/o music conditions of the participants (lag = 7). We conducted false nearest neighbors analysis on the baseline trials which gave a range of embedding dimensions from 2 to 6 across participants. Thus, we used an embedding dimension of 3 since most were between 3 and 4, and because we filtered out individual limb contributions and kept only timing data in our sinusoidal-like filter. We used the parameter previously calculated (time delay, embedding dimension) and set the radius to 10% of phase-space. We set a window for the phase synchronization of 12 seconds based on both trial length and visual inspection of individual trials which provided a discernable pattern in recurrence rates. We calculated baseline-levels (i.e., chance) synchrony by comparing participants' movements in the baseline condition with a) their confederate's baseline

trial in that session for baseline interpersonal synchrony and b) the 128 bpm pulse of the music for baseline music synchrony.

Statistical Analysis

All analyses were conducted in R (4.0.2). Preliminary analysis showed three participants could not synchronize with their partner in the intentional w/o music condition ($n = 1$ from the agreeable & $n = 2$ from the disagreeable conditions). These three participants were removed from all analyses because they could not intentionally synchronize to the confederate.

To examine the effects of agreeability on the self-report measures, we used Wilcoxon's W (non-parametric t -test) and report the effect size using *Cohen's d* for comparison with previous studies.

We examined the effect of agreeability on phase synchrony with the confederate and the music in each condition, using a $2 \times 2 \times 4$ mixed ANOVA with agreeability (between-subjects), auditory source (within-subjects), and instruction condition (within-subjects), together with Tukey-like (MVT) corrected contrasts (afex package; 0.28-1, Singmann et al., 2015; emmeans package 1.5.5-1, Lenth et al., 2021). In addition to the three experimental conditions (spontaneous (music on), intentional (music on), and intentional (music off)⁵), we also included the baseline (chance) synchrony levels (either with music or confederate) as an additional, fourth condition. We used Greenhouse-Geisser corrected degrees of freedom, and report generalized eta-squared effect sizes and Satterthwaite degrees for the contrasts. Results were visually displayed using ggplot2 (3.3.3; Wickham et al., 2016) packages. Sensitivity analysis using G^* power (Faul et al., 2007) showed we could detect a between-within interaction of $d = .63$ ($\eta^2 = .09$), at .80 power assuming .2 correlation between repeated measures (with our reduced $n =$

⁵ Synchrony with the music for the “intentional (music off)” condition was examined even though the music was not present to a) examine if any participants maintained the music rate, and b) to balance the ANOVA.

22). Finally, we computed Spearman correlations between our social questionnaire items and phase synchrony measures (confederate/music).

Confederate Timing Check

As we expected the confederate did not change their pace (mean IOI) as a function of synchrony condition $F(1.00, 20.03) = 2.00, p = .17, \eta_g^2 = .07$, social condition $F(1.00, 20.00) = 0.04, p = .84, \eta_g^2 = .001$, or their interaction $F(1.00, 20.03) = 0.06, p = .81, \eta_g^2 = .002$. Thus, the confederate provided a stable stimulus for the participant across conditions and trials.

Results

Social perception

The manipulation of agreeability was significant and large (Table 1). Participants liked the confederate more and felt that their interaction was pleasanter, smoother, and their relationship closer in the agreeable than in the disagreeable condition but did not report higher perceived synchrony with the confederate. The significant effects ranged in size from large ($d > .8$) to huge ($d > 1.2$).

Table 1

Ratings of the interaction with the confederate across the agreeableness condition. Comparisons made with Wilcoxon's W .

Question	Agreeable Mean	Disagreeable Mean	W	Cohen's d
<i>Bonding & Closeness</i>				
Likable	4.91	3.27	20.5*	1.17
Team	3.64	3.36	50.0	0.30
Unconnected	2.36	3.09	81.0	-0.70
Closeness	3.09	1.91	28.0*	1.04
Desired Closeness	3.73	3.64	59.5	0.05
<i>Quality of the Interaction</i>				
Pleasant	5.09	3.36	22.0*	1.30

Smooth	4.64	3.18	26.5*	1.11
Stressful	1.91	3.09	87.0†	-0.84
<i>Perceived Confederate Synchrony</i>				
(i.e., % Time sync)	3.82	3.63	52.5	.21

† $p < .1$, * $p < .05$

Behavioral Synchrony

Agreeability manipulation

Despite the effectiveness of the agreeability manipulation, the three-way mixed ANOVA (Figure 1) showed that the agreeableness condition (agreeable vs. disagreeable confederate) did not affect behavioral synchrony, $F(1, 20) = 0.45, p = .51, \eta_g^2 = .003$, nor did the agreeableness condition interact with either instruction condition, $F(2.04, 40.74) = 1.05, p = .36, \eta_g^2 = .01$, or auditory source (confederate vs. music), $F(1, 20) = 0.46, p = .51, \eta_g^2 = .006$. The three-way interaction was also not significant, $F(2.08, 41.54) = 0.97, p = .39, \eta_g^2 = .02$. Thus, the following results will be collapsed over agreeableness condition.

Instruction manipulation

There was an effect of instruction condition, $F(2.04, 40.74) = 62.00, p < .001, \eta_g^2 = .41$. Similarly, there was also a main effect of source where people overall were more synchronized with the confederate than the music, $F(1, 20) = 61.33, p < .001, \eta_g^2 = .44$. These main effects are qualified by an interaction between source and instruction condition, $F(2.04, 41.54) = 51.02, p < .001, \eta_g^2 = .48$. We followed up the effect of instruction condition at each level of auditory source (music vs. confederate).

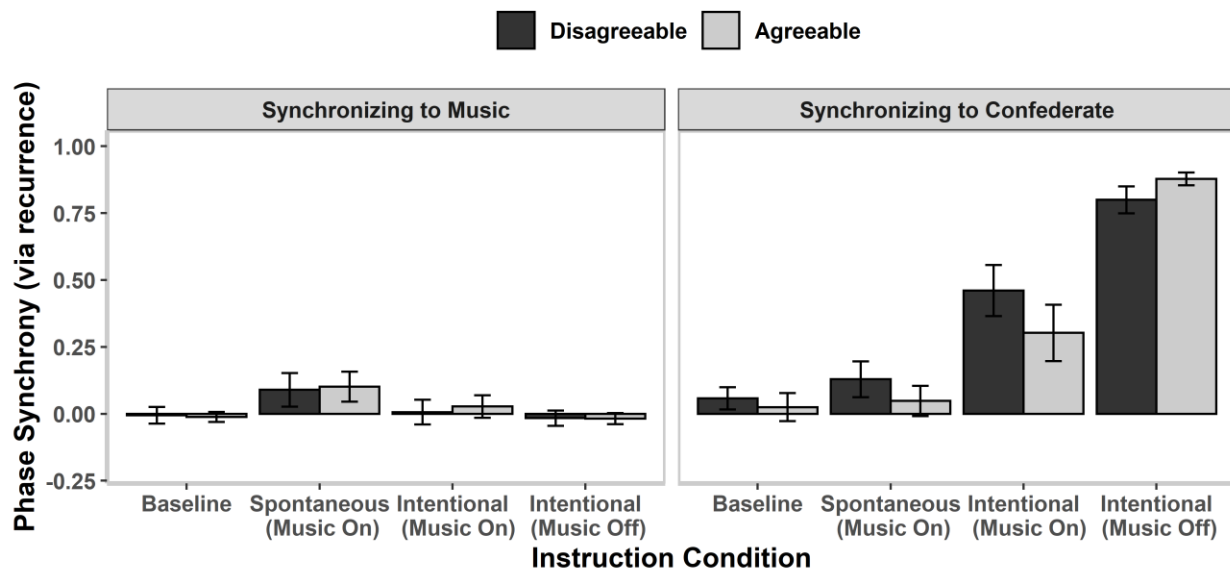
Synchrony to music. We compared synchrony at baseline to both the spontaneous (music on) and intentional (music on) conditions (left panel of Figure 1). Synchrony to music

was slightly higher in the spontaneous (music on) condition compared to baseline, $t(114) = 2.09$, $p = .07$, $d = 0.47$, but synchrony in the intentional (music on) condition did not differ from its baseline level, $t(114) = 0.51$, $p = .83$, $d = 0.12$.

Synchrony to confederate. Synchrony to the confederate did not differ from baseline for the spontaneous (music on) condition, $t(114) = 0.95$, $p = .71$, $d = 0.22$; however, intentional synchrony with the confederate did increase relative to baseline for both the intentional (music on), $t(114) = 6.83$, $p < .001$, $d = 1.54$, and intentional synchrony (music off) conditions, $t(114) = 16.02$, $p < .001$, $d = 3.62$ (right panel of Figure 1). Furthermore, synchrony with the confederate increases from intentional (music on) to the intentional (music off), $t(114) = 9.18$, $p < .001$, $d = 2.07$.

Figure 1

Phase behavioral synchrony to music and confederate across instruction conditions and agreeableness conditions. Error bars represent one within-subject corrected standard error (Cousineau & O'Brien, 2014).



Post-hoc analysis

While the manipulation failed to cause an overall change in the behavioral synchrony to the confederate (right panel), we ran a post-hoc analysis (using a Welch's t -test) for the condition that provided the closest comparison with the prior literature. In the intentional (no music) condition, synchrony was non-significantly higher with an agreeable partner ($M = .88, SD = .08$) than when the partner was disagreeable ($M = .80, SD = .16$), $t(14.06) = 1.44, p = .17, d = 0.61$. The effect size reported is smaller than the previously reported for a visual context ($d = .87$).

Behavioral/Perceived Synchrony and Social Questionnaire

Finally, we examined if behavioral and perceived synchrony were related to perceptions of closeness and the quality of the interaction using Spearman correlations. Behavioral synchrony to the confederate or the music was not related to bonding/closeness or the quality of the interaction (see Table 2). However, the perceived synchrony was positively associated with both likability of the interaction partner and feelings that the two were a team.

Table 2

Spearman correlations between social questionnaire items with actual behavioral synchrony with the confederate, and with music, by instruction condition.

Question	Synchrony with Confederate				Synchrony with Music	
	Spont (Music On)	Intentional (Music On)	Intentional (Music Off)	Perceived Confederate Synchrony	Spont (Music On)	Intentional (Music On)
<i>Bonding & Closeness</i>						
Likable	-.25	-.04	.01	.46*	.002	.02
Team	-.12	.08	.10	.48*	-.003	.09
Unconnected	-.05	-.27	-.35	-.24	-.17	.15
Closeness	-.19	-.25	-.001	.23	.02	.10
Desired Closeness	.05	-.11	-.22	-.28	-.19	-.01
<i>Quality of the Interaction</i>						
Stressful	-.14	.01	-.27	-.12	-.23	-.15
Smooth	-.01	-.12	-.01	.26	.13	.38†
Pleasant	-.07	-.31	.06	.16	.19	.41†

<i>Perceived Confederate Synchrony</i>						
(i.e., % Time sync)	.21	.04	.04	-	.38	.02

† $p < .1$, * $p < .05$

Together, Tables 1 and 2 reveal a complex pattern of relationships. Agreeability increased feelings of bonding on four of nine dimensions (close, likable, pleasant, and smooth interaction), but did not affect perceived synchrony. Two aspects of bonding (likable, being a team) were positively related to perceived synchrony, but only likable was affected by agreeability. This suggests that participants' perceptions of synchrony drove some of their impressions of the confederate more so than actual levels of behavioral synchrony.

Discussion

Our agreeability manipulation was successful in increasing the likability of, and quality of interaction with, the confederate. Despite this success, we did not replicate previous findings that bonding increases interpersonal synchrony when measured objectively by behavior (Miles et al., 2010; Zhao et al., 2017). In our study, participants spontaneously synchronized, weakly, with the music rather than with the sound of the confederate's movements only in one condition. When participants were given no instructions about synchronization, the techno-style music that we used appears to have provided a conflicting source of attraction from the sound of the confederate's movements. When instructed to synchronize with confederate, participants struggled to maintain strong synchrony when the music was playing.

We expand the previous finding that introducing a musical stimulus disrupts auditory interpersonal synchrony (Demos et al., 2012). We also replicated the finding that people spontaneously synchronize to music, although the effect was weaker than reported by Demos et al. (2012), probably due to the presence of a competing auditory source in the present study. Unlike Demos et al.'s (2012) finding that behavioral synchrony to music increased perceived

connectedness, we found instead that synchrony to music was only weakly related to perceptions of the interaction. One way to conceptualize this finding is by thinking of the confederate and music as competing attractors vying for the attention of the participant. This creates a rhythmic dissonance in that whichever rhythm the participant chooses is always in conflict with the other (i.e., the participant cannot block out the other rhythm). We speculate that the reason the music disrupted interpersonal synchrony in some conditions was because it was more acoustically complex than a simple egg-shaker sound. Previous work on competing metronomes has also shown even experts have difficulty filtering conflicting, equally attractive signals (Repp, 2003). Perhaps a stronger manipulation of either target attractor would allow us to tease apart how the social characteristics of an attractor affect synchrony (e.g., using the participant's favorite song vs. an incredibly rude/nice confederate). We leave for future inquiry the question of whether increasing the salience of the partner relative to the music or decreasing the difference in their tempi (Zamm et al., 2015), might increase interpersonal synchrony.

Participants who perceived themselves as synchronizing more with the confederate liked the confederate more and felt more like a team with her. This was the case even though perceived synchrony was unaffected by the agreeability manipulation and was unrelated to interpersonal synchrony. Thus, liking and social bonding depended on the perception of synchrony but not on actual, behavioral synchrony. This suggests that the positive effects of synchrony on social bonding seen in an array of synchrony studies (see Mogan et al., 2017 for meta-analysis) may depend upon a more complex relationship involving both the success of the physical interaction (e.g., behavioral synchrony) and the social-cognitive perceptions of that interaction. Future studies should manipulate these social-cognitive perceptions more directly to tease out these relationships.

There are four limitations to this study worth noting. First, the sound levels were standardized between participants, the loudness of the maraca sounds was not balanced with the music beyond what seemed natural to the experimenters. The salience of the loudness could contribute to differences when comparing synchrony with the confederate to music synchrony. Second, the participants had no prior exposure to the music, meaning the participants should not have felt any strong attachment to the music. Had the participants brought in their own selection of music, it may have created a stronger manipulation and source of attraction. Third, while the sample was sufficient to test claims about how liking affects synchrony, a larger sample is necessary to determine how individual differences in previously established social-cognitive constructs moderate these results (e.g., empathy and anticipation/adaptation skills, see Keller et al., 2014 and Savage et al., 2019 for reviews). In fact, there still may be a small/medium effect of liking on behavioral synchrony; however, a replication powered to detect smaller effects is necessary. Finally, our study measured synchrony in a context where only auditory information is available. Liking may affect synchrony in contexts where both audio and visual information occurs (e.g., during conversations).

In summary, we tested whether liking affects behavioral synchrony with a confederate and music, as well as perceived synchrony with that confederate. We found no significant effect of liking on behavioral synchrony and no relationship between behavioral synchrony and participants' perceptions of the confederate. It seems perceptions of synchrony may be a more important to social bonding than actual levels of synchrony in an auditory context.

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