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Drumming in time is easy: social bonding effects of synchrony arise from reduced cognitive load

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The synchrony-bonding effect has often been observed, but the mechanisms behind it remain poorly understood. Numerous possible mechanisms have been proposed, however simple perceptual processing explanations have been largely ignored. The present study tested a theory based on processing fluency across two controlled experiments. In the first study, 104 participants completed a drumming task in a within-subjects design in which they also completed a secondary visual attention task. We found that when drumming in non-synchrony, performance was worse on the secondary task, indicating increased cognitive load. In the second study, 82 participants performed a similar drumming task, however instead of the secondary task they were asked to self-report how difficult they found the tapping task and how much they liked the person they were drumming with. Participants reported that drumming in synchrony felt easier and produced greater feelings of social connection than drumming out of synchrony. Taken together, these studies suggest that synchrony may promote processing fluency, which in turn leads to prosocial effects.

Keywords: Synchrony, Entrainment, Social bonding, Visual attention, Evolution

1. Introduction

Synchrony appears in all human cultures in the form of music, dance and some sports (McNeill, 1997). It has previously been observed that people tend to like each other more, and exhibit more pro-social behaviour, after synchronised action (Vicaria & Dickens, 2016; Rennung & Göritz, 2016; Mogan et al., 2017). Therefore, it has been suggested that a possible evolutionary function of musicality is to facilitate social bonding (Savage et al., 2021). However, the precise cognitive mechanisms involved in this synchrony-bonding effect remain poorly understood. One possibility is that interpersonal synchrony makes other people easier to process, and processing fluency may influence perceptions of social closeness. If synchrony is easier to process, then this could reframe the synchrony-bonding effect as a processing fluency effect.

Processing fluency is a general factor influencing the judgement of stimuli. It states that people will usually prefer stimuli that are easy to process, either because of the structural simplicity of the stimulus or from prior exposure to the stimulus (Reber et al., 1998).

Synchronised stimuli are likely to be perceived as one stimulus (Hukin & Darwin, 1995). There are fewer cognitive resources required to perceive one object rather than two (Alnaes et al., 2014; Hughes et al., 2013; Zeamer & Fox Tree, 2013), which means synchronised stimuli may be more fluent to process as they are only perceived as one stimulus. Some initial studies indicate that this may be true in the visual domain (Bamford, Tarr & Cohen, 2023), however it remains to be tested for multi-modal stimuli.

Study 1 aimed to test the assumption that synchrony is easier to process than non-synchrony in a synchronised tapping task. It employed a dual task paradigm, in which the processing load of the primary task was measured by the performance impact upon a secondary task (Abernethy, 1988; Huang & Mercer, 2001). In this instance, the primary task was to maintain synchrony with a target stimulus. There were three conditions: synchrony, non-synchrony, and a control condition with only one moving hand. The secondary task was a visual search task in which participants had to identify a target letter amongst a range of distractor letters on screen (Treisman, 1977). This visual search task was chosen as each trial was expected to take longer than the period of the beat in the tapping task (0.5s). Previous studies have shown that participants will often synchronise their responses between tasks when provided with a regular beat (Killingly et al., 2021) and this needed to be avoided to measure reaction time. It was expected that performance on the secondary task would be highest in the synchrony and control conditions, compared with non-synchrony. If the stimuli are being streamed together in synchrony, then there should be no difference between two hands moving in synchrony and one hand moving in the control condition.

2. Methods (Study 1)

2.1. Participants

104 participants (66 female, 35 male, 3 other) were recruited from the student population at the University of Western Australia. They had a mean age of 23.6 (SD = 8.73, range = 18 to 61). All participants reported having normal or corrected-to-normal vision and hearing. This study was approved by the ethics

boards at the University of Oxford (SAME_C1A_19_002) and the University of Western Australia (00007908).

2.2. Materials

Video stimuli were created with an actor tapping in time with a metronome on the desk in front of him. These videos were matched side-by-side to create the conditions. Each stimulus had a video with 120 BPM tapping on the left, with the right video tapping at either 120 BPM (synchrony), 110 BPM (non-synchrony) or not moving at all (control).

A letter search task was superimposed on the video stimuli (see Figure 1). This consisted of 9 letters, in addition to either an ‘N’ or an ‘M’. The videos and the letter search task were presented using PsychoPy (script available upon request).

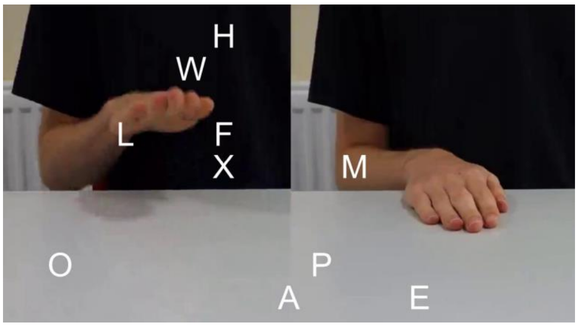


Figure 1. Screen capture during the experiment. The participant was asked to tap in time with the target on the left. In this instance, the distractor on the right was in the still condition. Letters for the visual search task appear superimposed on top of the video.

2.3. Procedure

Participants were briefed, and then allowed to guide themselves through the protocol within PsychoPy. They completed three short blocks of practice trials, one in each condition in randomised order. After the practice trials, participants were presented with the main task in six blocks (50 letter search trials per block). Each block was in one stimulus condition and condition order was randomised, with each condition being presented twice. At the end of the study, participants were fully debriefed about the aims and hypotheses of the study.

Mean reaction time on correct trials (RT) and error rate (ER) were recorded for each block. A combined performance score (ER/RT) was then calculated for each participant in every block.

3. Results (Study 1)

A repeated-measures ANOVA was used to test the effect of condition on performance. The data violated the assumption of sphericity, $W = 0.877$, $p < .01$, so a Greenhouse-Geisser correction was applied. The corrected RM-ANOVA found a large, significant effect, $F(2, 206) = 68.63$, $p < .001$, $\eta p^2 = 0.400$ (see Figure 2). Post-hoc analysis revealed that performance was significantly better in synchrony compared with non-synchrony, $t(103) = 10.00$, $p < .001$, $d = 0.528$, and in the control condition compared with non-synchrony, $t(103) = 8.68$, $p < .001$, $d = 0.467$, but no difference was observed between the synchrony and control conditions.

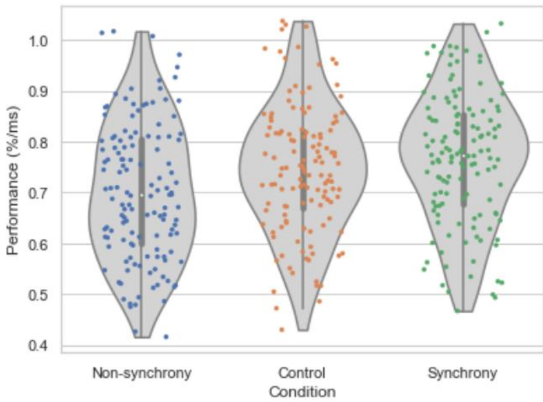


Figure 2. Performance (ER/RT) by condition. Each point on the scatter plots represents a participant. Violin plots show the distribution of scores, and the box plot within show this by quartiles.

4. Methods (Study 2)

Study 2 used similar methods, but expanded upon Study 1 by investigating social bonding effects of the conditions. It had the addition of subjective ratings after each condition, but did not include the secondary task. It aimed to test whether the social bonding effects of Synchrony could be attributed to the reduced processing load observed in Study 1.

4.1. Participants

82 participants (60 female, 22 male) were recruited from the University of Western Australia with a mean age of 20.04 (range = 18 to 40). All participants reported having normal or corrected-to-normal vision and hearing. Participants all gave informed consent and were compensated for their time with course credit. This study was approved as an extension of Study 1 under the same ethics applications.

4.2. Materials

Video stimuli were created to be similar to those used in Study 1. However, Study 2 used multiple actors, and they beat on a drum instead of a table. The actors were recorded drumming at 120, 113.5, and 80 BPM. Stimuli were then created by pairing these recordings together into three conditions: synchrony (120:120), complementary (120:80), and non-synchrony (120:113.5).

A battery of self-report questions was also included. These were as follows: ‘Please rate how much you like the person on the LEFT’, ‘Please rate how connected you felt to the person on the LEFT’, ‘Please rate the difficulty of the task’, and an adaptation of the Inclusion of Other in the Self (IOS) scale (Aron et al., 1992). The IOS is usually presented as a 7-point scale but this study used a continuous measure in which participants could drag the ‘self’ circle into the position which best describes their relationship. All these continuous scales were measured with an arbitrary range of 0 to 100.

In Study 2, participants were also given a djembe to drum on, to make the study feel more natural than tapping on a desk and to ensure their experience was similar to the people on the video.

4.3. Procedure

The experiment was run using PsychoPy and participants could guide themselves through the protocol at their own pace. After being presented with written instructions on screen, participants were given the opportunity to practice using the sliding scales and to familiarise themselves with the drum in a short practice trial with only one virtual drumming partner.

Participants were then presented with six trials. Each trial consisted of a video stimulus of two drummers and participants were asked to drum in time with the drummer on the left-hand side of the screen. The drummer on the right may be moving in or out of time with their target drummer, depending upon which of the three conditions that trial was in. Each participant completed each of the conditions twice. After each trial, participants were given the battery of self-report questions.

The three questions about the participants' relationship with the target drummer were averaged to create a combined 'bonding' measure, similar to the procedure of Tarr and others (2016).

5. Results (Study 2)

Repeated-measures ANOVAs found significant effects of condition on both self-reported difficulty, $F(2, 156) = 54.42$, $p < .001$, $\eta p^2 = 0.410$ (Figure 3), and bonding, $F(2, 156) = 25.58$, $p < .001$, $\eta p^2 = 0.248$ (Figure 4). The data for difficulty violated the assumption of sphericity, so a Greenhouse-Geisser correction was applied. Bonferroni corrected post-hoc comparisons found that bonding was significantly lower in non-synchrony compared with synchrony, $t(78) = -6.287$, $p < .001$, and also lower in non-synchrony compared with complementary, $t(78) = -5.253$, $p < .001$. On the difficulty measure, complementary was lower than non-synchrony, $t(78) = -6.660$, $p < .001$, complementary was higher than synchrony, $t(78) = 4.761$, $p < .001$, and non-synchrony was higher than synchrony, $t(78) = 8.585$, $p < .001$.

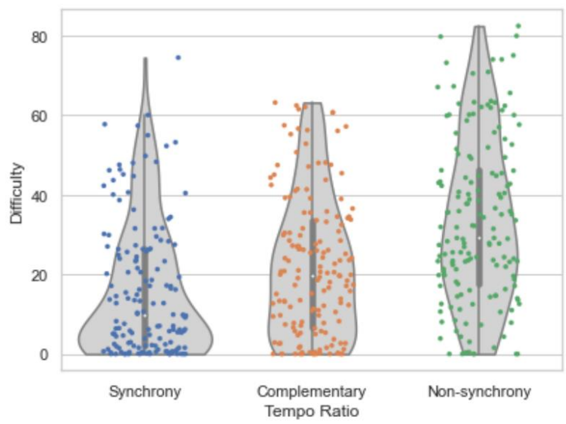


Figure 3. Perceived difficulty by tempo ratio condition. Scatter plot points each represent a participant's score within a condition. Violin plots show distribution and the box plot within shows quartiles.

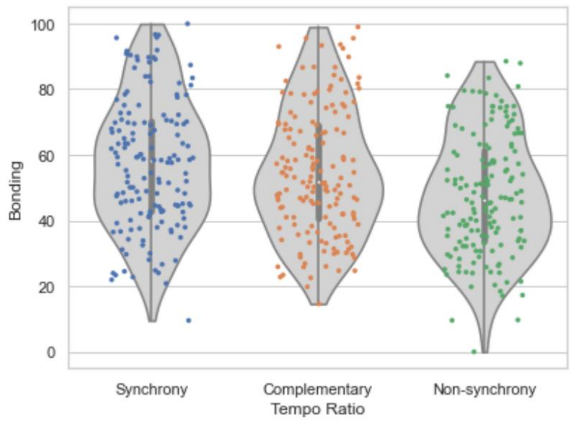
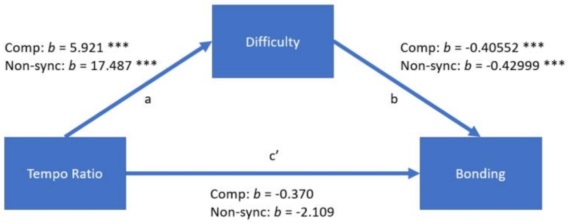


Figure 4. Self-reported bonding by tempo ratio condition. Scatter plot points each represent a participant's score within a condition. Violin plots show distribution and the box plot within shows quartiles.

Further analysis tested whether the observed effect of tempo ratio may be mediated by difficulty. Tempo ratio was divided into two binary contrast variables comparing the non-synchrony and complementary conditions to synchrony (the reference condition). Both conditions increased difficulty and reduced bonding when compared with synchrony. The analysis found a significant indirect effect of the mediator (see Figure 5).



Tempo Ratio	Indirect effect (ab)	Direct effect (c')	Total effect (c' + ab)
Complementary	-2.422 ***	-0.334	-2.756 *
Non-synchrony	-7.514 ***	-2.217	-9.731 ***

Figure 5. Mediation model showing the direct, indirect and total effect of tempo ratio on bonding, as mediated by difficulty. Tempo ratio is split into two factors comparing complementary and non-synchrony to synchrony (the reference condition). (* $p < .05$, ** $p < .01$, *** $p < .001$)

6. Discussion

These two studies aimed to test whether synchrony is easier to process than non-synchrony, and whether this could contribute to the synchrony-bonding effect. Study 1 demonstrated decreased performance on a secondary visual attention task during non-synchronous tapping. This is consistent with previous literature, which observed longer processing times for non-synchronous stimuli in a visual attention task (Bamford et al., 2023). Importantly, no difference was found between the synchrony and control conditions. In this instance, the control condition had only one hand tapping in the video stimulus. Since there was no increase in processing load from adding a second hand in synchrony, this implies that the two hands were likely streamed together and perceived as one, consistent with previous research suggesting that synchrony is a cue for grouping (Hukin & Darwin, 1995).

Study 2 expanded upon this by including self-reported social bonding measures. There was a significant effect of synchrony condition on self-reported social bonding, consistent with previous literature on the synchrony-bonding effect (Vicaria & Dickens, 2016; Rennung & Göritz, 2016; Mogan et al., 2017). However, when including self-reported difficulty in a mediation analysis, we found that self-reported task difficulty totally mediated the social bonding effects of synchrony. Taken together, this provides support for the notion that the synchrony-bonding effect may be part of a general processing fluency effect.

The measures of social bonding used in Study 2 are well established in the previous literature, specifically asking about 'connection', 'liking' and a modified Inclusion of Other in the Self (IOS) scale (Aron et al., 1992). Although, there were no measures of pro-social behaviour in this study, which may be separate to feelings of social closeness and should be examined further. Study 2 also only included a subjective measure of difficulty, but the behavioural results of Study 1 are consistent with these self-reported difficulty ratings.

Both studies used similar stimuli and asked participants to tap along to these videos. This only allowed for uni-directional coordination: participants had to adapt to the video, but the video would not adapt to them. Real-world synchrony tasks usually involve some degree of mutual adaptation (Keller, 2013), and the processing load for bi-directional synchrony should be studied further. The stimuli here also involved relatively simple isochronous tapping, unlike real music. Study 2 did include three levels of complexity, based upon the tempo ratios used to construct the stimuli. In this instance, the complementary condition had a tempo ratio that allowed for a rhythm to emerge, and the results indicated that the complementary condition was of medium difficulty between total synchrony and non-synchrony. Future studies should investigate these factors further, moving away from simplistic synchrony vs non-synchrony tasks and towards trying to find optimum levels of processing load.

In the present study we have found that some of the effects of synchrony may in fact arise from a general processing fluency effect, rather than from synchrony, *per se*. This is an important finding in demystifying the cognitive mechanisms behind the synchrony-bonding effect. Previous research has suggested that the synchrony-bonding effect may be attributed to activation of the endorphin system, which is also active in the social bonding behaviours of non-human primates (Tarr et al., 2014). It has also been suggested that the hedonic rewards of processing fluency may engage the endorphin reward system (Reber, 2011). The present findings suggest a possible connection between these cognitive and neurohormonal mechanisms, but further research would be required to fully understand this pathway. Processing fluency effects may also be present across many domains of music perception (Anglada-Tort et al., 2023), and not just in rhythmic synchrony, suggesting that a multi-modal approach to studying the social bonding effects of music should be adopted.

Overall, the present study provides initial support for a fluency-through-synchrony account of the synchrony-bonding effect. It establishes a new paradigm for studying synchrony in connection with processing fluency, and advances a deeper understanding of the possible cognitive mechanisms behind this effect. Two people coordinating through music, may thus be mutually reducing each other's processing load. This low-level perceptual processing effect may have been leveraged by early humans to create and reinforce social bonds, ultimately driving the evolution of our ability for sensorimotor synchronisation.

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