

Resonance Constraints On Between-Person Polyrhythms

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What is the mechanism underlying a behavioural *encounter* (Reed, 1996) and does it depend on the modality of informational contact? From the perspective of complex systems, an explanatory basis for social inter-action may be found in the form of *information*-based coordination dynamics (Treffner & Kelso, 1999). Rather than assuming causal primacy of neural substrate or mental representation, one instead investigates the relatively macroscopic behavioural patternings as described and predicted by dynamics and the theory of coupled oscillators. These models are based on the fundamental constraint of *relative stability*. Thus, such models of social encounters emphasise dynamical and, ultimately, *informational* couplings between individuals that are implemented by optic (Schmidt & Turvey, 1994) and acoustic fields, although the latter may be almost four times weaker in coupling strength (Schmidt & McGregor, 1997).

This research asked whether the social coordination of between-person polyrhythms conforms to the same stability-based resonance constraints shown to exist during within-person polyrhythms (Treffner & Turvey, 1993). In that research, evidence was found to support a theoretical model based on a person's hands considered as two coupled oscillators whereby resonance or entrainment (whole number frequency ratios such as 1/2 or 2/3) emerge as a natural property of the coupled oscillatory system. Further, the relative stability of the polyrhythmic ratios decrease as one descends levels in a number-theoretical hierarchy known as the Farey tree (Fig. 2). In the present research we asked whether optic, acoustic, or haptic information differentially couples interpersonal dyads. If so, then more transitions are to be expected from difficult, less stable ratios (e.g., Level 4) to easier, more stable and neighboring ratios (e.g., Level 2). Further, in conformity with the

theoretical availability of resonances, there will be more *unimodular*, or “Mod1” transitions than non-unimodular or “NonMod1” transitions where unimodularity is defined for neighboring ratios p/q and n/m as $|p*n - q*m| = 1$ (see Fig. 2 for shifts to “neighboring” Mod1 ratios).

Method

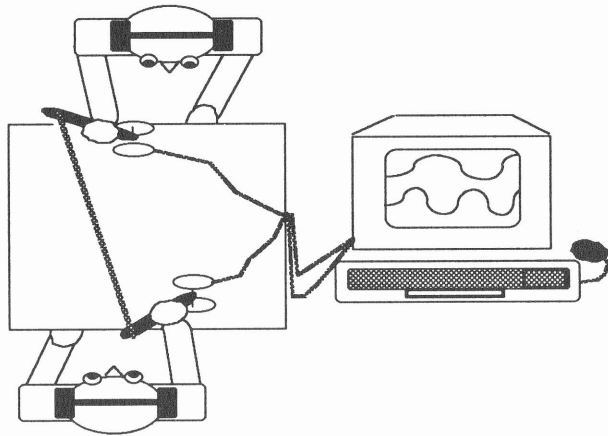


Figure 1. Two individuals during a dynamic encounter either looking, hearing, or feeling each other.

Using a hand-lever, each individual in each of 12 pairs of undergraduates was responsible for a different frequency of supination-pronation of the preferred hand thus producing a between-person polyrhythm (2:5, 3:5, 5:7, or 5:8) (Fig. 1). During induction, each individual synchronised hand motion with headphone-presented high-pitched beeps such that in the right ear (RE) was the metronome and in the left ear (LE) was a beep generated as the handle passed through the vertical. The participant’s objective during induction was to synchronise to the metronome (“superimpose” the metronome with their own beeps). During continuation, when the metronome stopped, the individual had to remember and maintain the initial frequency under informational perturbation from the other person’s movement.

There were three modalities of informational contact (optic, acoustic, haptic) during continuation. In the optic condition, the LE and RE were silent and each participant visually attended to the other’s

handle. In the (blindfolded) acoustic condition, using metronome pulses, the LE specified the self-rhythm, and the RE specified the rhythm produced by the partner. There were two (blindfolded) haptic conditions. During both induction and continuation, either one (haptic1) or two (haptic2) quality under-garment elastic bands were attached between the handles thus producing a haptically-perceivable continuously changing force (Fig. 1). During continuation, the headphones were silent and individuals had to haptically perceive the situation. Each trial lasted 60 secs (5 transient—15 induction—10 transient—30 continuation). At issue was whether the initial between-person frequency ratio established during induction transformed into a simpler ratio during continuation according to the stability and theoretical availability and of the resonances in the Farey tree (Fig. 2). The average frequency ratio over the continuation period was found and this value was conservatively parsed as either a whole-number ratio (e.g., $0.521 \approx 0.5 = 1/2$) or not (e.g., $0.53 \neq 0.5 = 1/2$). The parsing method was analogous to that used in Treffner and Turvey (1993) whereby a tolerance window around a whole number ratio was determined using well-defined maximum half-widths for all ratios from a given level in the Farey tree (Level 0: .084, Level 1: .028, Level 2: .017, Level 3: .011, Level 4: .009, Level 5: .016).

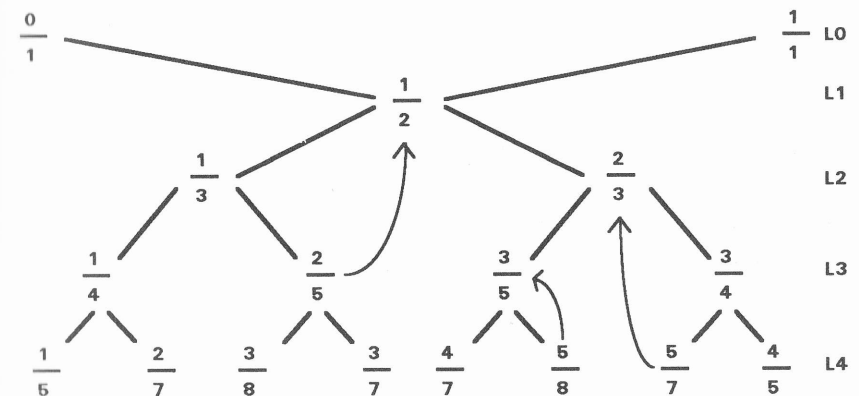


Figure 2. The Farey tree showing ratios from levels L0—L4 where given p/q and p'/q' , the intermediary is $(p + p')/(q + q')$. Several unimodular (Mod1) shifts are also indicated.

Results and Discussion

As in the study by Treffner and Turvey (1993), repeated measures analyses of variance were conducted with the dependent measure being the total percentage of all trials that exhibited a particular type of transition, and with factors of Coupling type and Ratio. Regarding trials that did not change ratio, coupling was significant [$F(3, 33) = 3.46$, $p < .05$] with significantly more trials undergoing no transition with acoustic coupling (8.33%) than with optic (4.69%), haptic1 (2.60%) or haptic2 (2.60%) coupling. Thus, acoustic information appeared to foster the strongest coupling for allowing an individual to maintain a rhythm in the face of a partner's behaviour. Regarding trials that shifted to 1/1 (considered the strongest attractor for bimanual coordination), coupling was significant [$F(3, 33) = 4.37$, $p < .01$] and there were more transitions to 1/1 for optic trials (3.65%) than for acoustic (1.04%), haptic1 (0.52%) or haptic2 (0.52%) conditions, (all $p < .01$). This suggests that visual information provides the strongest coupling for supporting transitions to ubiquitous and simple 1/1 synchrony. Regarding transitions to 1/2 (another strong attractor), coupling was significant [$F(3, 33) = 2.91$, $p < .05$] with both acoustic (12.5%) and haptic2 (12.5%) inducing more transitions to 1/2 than did optic (7.29%) or haptic1 (6.25%) coupling (both $p < .05$). This suggests that both acoustic and haptic2 coupling (but not optic or haptic1) are more likely to induce a transition to the more complex coordinative pattern of 1/2. In addition, ratio was significant [$F(3, 33) = 12.86$, $p < .0001$] with more transitions to 1/2 occurring from 3/5 (17.19%) and from 5/8 (15.63%) than from 2/5 (4.69%) or 5/7 (1.04%) (both $p < .001$). Interestingly, both 3/5 and 5/8 are Fibonacci ratios and have been shown to be maximally unstable in many physical and behavioural experiments (Treffner & Turvey, 1993).

Ratio	Observed			Expected		
	Mod1	NonMod1	Other	Mod1	NonMod1	Other
2/5	44.79	29.17	26.04	16.67	80.00	3.33
3/5	24.48	32.81	42.19	16.67	80.00	3.33
5/7	25.52	42.71	31.77	13.33	83.33	3.34
5/8	24.48	38.54	36.98	13.33	83.33	3.34

Table 1. Observed and expected frequencies of Mod1, Nonmod1, and Other transitions, as a function of Ratio.

The main hypothesis of whether resonance constraints determine behaviour was tested using a comparison of the proportion of Mod1 versus NonMod1 transitions. A χ^2 analysis confirmed that the null hypothesis that one would expect more NonMod1 than Mod1 shifts (given greater theoretical availability of NonMod1 ratios; Table 1) was to be rejected ($p < .0001$ for each ratio). Thus, there were effectively more Mod1 than NonMod1 shifts. This supports the main hypothesis that resonance constraints and their geometrical distribution according to the Farey tree determines between-person polyrhythm-like coordination in a similar manner to within-person coordination. In addition to the differential effects of informational coupling, the results encourage further investigations of the dynamical underpinnings of behavioural encounters (Treffner & Kelso, in press).

References

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