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Coordinated Responding Under Concurrent Schedules of Reinforcement

Respostas Coordenadas sob esquemas de reforçamento concorrente

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Abstract

The present study investigates the dynamics of choice when the reinforced unit consists of coordinated responses between two individuals operating concurrent schedules of reinforcement. The experimental design involved pairs of human participants engaging in coordinated responses on concurrent variable-interval (VI-VI) schedules. In a computer game, each participant had the option to place their playing piece next to their partners in two distinct keys, with reinforcement delivered contingent on the VI-VI schedules. The findings revealed that two pairs exhibited sensitivity to changes in reinforcement rates, with their coordinated responses being influenced by each other's behaviors. In contrast, the third pair demonstrated control over each other's responses, yet their coordinated responses remained insensitive to variations in reinforcement rates. Overall, this study contributes to our understanding of coordinated responses in the context of paired participants within concurrent variable interval schedules of reinforcement, shedding light on the factors that govern choice behavior when social stimuli is a variable of interest. The findings have implications for the matching law and its applicability in understanding the dynamics of coordinated responses.

Keywords: coordinated responses, pairs of participants, concurrent schedules of reinforcement, matching law.

Resumo

Este estudo investigou escolhas dinâmicas em esquemas concorrentes nas quais a liberação de consequências exigiu respostas coordenadas de dois indivíduos. O delineamento experimental envolveu duplas de seres humanos, engajados em respostas coordenadas sob esquemas de intervalos variáveis (VI-VI). Em um jogo de computador, cada participante tinha a possibilidade de mover uma peça para duas posições diferentes. Foi exigido que as duas peças estivessem próximas (i.e., na mesma posição). Os resultados de duas duplas sugerem que as respostas coordenadas foram sensíveis à mudança na taxa de consequências. Sendo o comportamento de cada membro da dupla influenciado pelo comportamento do parceiro. De modo contrário, a terceira dupla, apesar de apresentar o controle do comportamento de um parceiro pelo outro, não apresentou sensibilidade de respostas coordenadas às variações na taxa de consequências. De modo geral, este estudo contribui para a compreensão de respostas coordenadas de duplas de participantes em esquemas concorrentes, jogando luz sobre eventos que determinam escolhas quando estímulos sociais são variáveis de interesse. Os resultados encontrados possuem implicações para lei de igualação e sua aplicação para compreensão de respostas coordenadas.

Palavras-chave: respostas coordenadas, duplas de participantes, esquemas concorrentes, Lei da igualação.

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For the past 60 years, concurrent schedules of reinforcement have been used to study choice within behavior analysis. Herrnstein (1961) study of pigeons pecking on concurrent schedules of reinforcement led to the development of the Matching Law, a quantitative model of choice. Pigeons were trained to peck on two keys, each key operating independently and with Variable Interval (VI) schedules of reinforcement, where the first response after a variable time interval is reinforced. Herrnstein (1961) found that the relative rate of responses matched the relative rate of reinforcement, suggesting that organisms allocate responses proportionally to obtained reinforcers (Poling et al., 2011). Herrnstein (1961) suggested the following equation for the matching law, later known as the strict matching law:

$$\frac{B_1}{B_1+B_2} = \frac{R_1}{R_1+R_2} \qquad \text{(Equation 1)}$$

In equation 1, *B* is the behavior for each of the keys, and *R* is the reinforcement obtained from each of the alternatives. Furthermore, Herrnstein (1970) suggested that all behavior is initially choice behavior. An organism will always have the option to emit other responses than the responses that the experimenter is studying, for example, scratching instead of pecking the key. In this sense, when an organism is emitting any response, the organism is at the same time, omitting another response.

Not all data on choice conformed to the strict matching law, as a result, Baum (1974) suggested the Generalized Matching Law (GML). The logarithm of the response ratio B1/B2 is plotted as a function of the logarithm of the reinforcement ratio R1/R2. The GML equation becomes:

$$log\left(\frac{B_1}{B_2}\right) = a\ log\left(\frac{R_1}{R_2}\right) + log\ b \qquad \text{(Equation 2)}$$

The *a* parameter in equation 2 is the fitted line's slope, which is a measurement of sensitivity. When the slope indicates a sensitivity value 1.0, it is considered to be perfect matching. However, it is often found that the sensitivity value deviates from one (Baum, 1974). Sensitivity values between 0.90 and 1.11 can be considered good approximations to matching (Baum, 1979), while it is more common to find undermatching (values lower than 1.0) than overmatching (values above 1.0) or matching. The other free parameter in equation 2 is the *b*, a measurement of bias, which indicates unaccounted preferences. In the absence of bias, the value of *b* would be zero. Unlike sensitivity, the bias parameter does not deviate from zero if all variables are accounted for (Baum, 1974). The third feature of the GML is the variance (r^2), which indicates how much of the variance of the allocation of the responses between the two alternatives that can be accounted for by the GML. The value of variance can be written either as a percentage from 0 to 100, or as a value between 0.00 and 1.00.

The matching law have proven to account for allocation of behavior across species studied under laboratory conditions – i.e., pigeons (Herrnstein, 1961), rats (Graft et al., 1977) and humans (Baum, 1975; Horne & Lowe, 1993). Outside the laboratory the GML have been applied to a broad specter of areas, from reducing problem behavior (Borrero & Vollmer, 2002), analyzing chess openings (Cero & Falligant, 2020), to strike selection in mixed martial arts (Seniuk et al., 2020).

The majority of concurrent schedules of reinforcement studies have been conducted in a laboratory setting, typically with one individual operating they keys at the time. However, humans are social organisms and encounter several situations where responses are reinforced dependent on others. Skinner (1953) described a social behavior as "the behavior of two or more people with respect to one another or in concert with respect to a common environment" (p. 297). Individual human behavior under concurrent schedules in social settings were first studied by Conger and Killeen (1974) when they placed a participant in a discussion group with confederates who changed their conversation feedback according to concurrent schedules. The confederates pretended to be other participants and agreed with the statements of the participant according to variable interval (VI) schedules, and measured how much time the participant spent talking to each of the confederates. Conger and Killeen found that the matching law accounted for how the participants allocated their behavior, and that the experiment showed that operant principles could be extended to social situations. Note that in this study the dependent variable is the allocation of the participants speech, and the concurrent VI schedules cueing the confederate's agreement are the independent variable.

A number of studies applying the GML to team sports have been conducted during the last two decades. Vollmer and Bourret (2000) applied the GML to study the allocation of two- and three-point shots by individual basketball players, and Poling (2011) studied the shot selection of individual baseball players. Both studies investigate the allocation of the behavior of an individual, in a social setting.

In team sports, the availability of reinforcers is often contingent on the response of more than one organism, for example, in a soccer match. The team's players need to pass the ball to each other until the last player scores a goal. Even that the last player is the one who scores the goal, the game depends on the coordinated behavior of all the players on the team. Each player decides whether to pass the ball to a teammate, attempt a dribble, take a shot from far away or to attempt a shot closer to the goal. In certain team sports, it is not always possible to allocate the team's response to one individual, but the outcome is an aggregate of the team's behavior. Reed et al. (2006) performed a team level descriptive analysis of American football (hereafter referred to as football) and found that the GML provided insight to the play-selection when analyzing pass versus rush choices. The dependent variable in Reed et al. (2006) were the teams joint behavior of choosing pass or rush play, while the independent variable were the defensive performance of the opposing team. While the objective of the Reed et al. (2006) did not aim to investigate team performance, it was not feasible to isolate individual behavior from one another, which resulted in a team level analysis.

Previous research has effectively examined contingencies at the group level. Litow and Pumroy (1975) examined the effectiveness of group-oriented contingencies in classroom settings. The authors asserted that certain classroom situations necessitate the application of group-oriented contingencies due to their economic feasibility and practicality. Specifically, the application of the same contingency to all members of a group is more practical than implementing individualized contingencies for each student. Cariveau et al. (2020) provides an example of a classroom scenario in which a teacher applies a criterion to all students in the class, with the reinforcement delivered to the entire group. It is important to note that while groups themselves do not exhibit behavior, it is the individual members of the group who do. It should be noted that while these studies utilized contingencies at the group level, concurrent schedules were not employed.

Other studies have reported variations in reinforcement schedules when comparing individual and group-level data. Grott and Neuringer (1974) studied groups of rats in an operant chamber. Three rats were placed in the chamber simultaneously. Each rat could individually press a lever to get access to water. A single lever operated on a variety of schedule conditions, providing reinforcement accessible to all the rats. The experimental task did not require the rats to cooperate, but the recorded data was the collected lever-presses by the entire group of rats. The responses of the group were found to be controlled by the reinforcement schedule similarly to individual rats working under similar conditions, but in contrast, the groups paused less and responded faster compared to rats working in isolation.

There have been published several studies with groups of individuals exposed to concurrent schedules of reinforcement (Reed et al., 2006; Reed et al., 2011), where the coordinated behavior of the individuals has been the unit of analysis. These experiments have been descriptive analysis, applying the principles of operant behavior from laboratory experiments. As in Grott and Neuringer (1974), there may be some differences in applying operant principles as reinforcement under concurrent schedules to a group of individuals, compared to one single individual.

Within the field of biology, Fretwell (1969) described an equation that was very similar to the Matching Law, called the Ideal Free Distribution (IFD). The IFD predicts how a group of foragers distribute their foraging across different habitats proportionally to the gained resources from those habitats. A generalized version of the IFD adapted from Baum (1974) included the sensitivity and bias parameters. The IFD equation have also been used to predict choice in groups of humans, as in Kraft et al. (2002) where a group of individuals had to choose different between different rows of chairs in order to get points. Gray (1994) describes the two equations as matching in individual level (GML) and group level (IFD). However, two important differences between the two equations are as follows: (a) the IFD matching is expressed in terms of resources available, while the matching law is expressed in the terms of resources obtained. (b) The IFD predicts behavior based on individuals in a group distributing themselves between different alternatives, the individuals need to take into account how many other individuals are present in each of the alternatives. The IFD cannot account for distribution of behavior where two or more individuals in a group coordinate their behavior to emit a coordinated response, as when football players make a pass, or a class of students are being silent or noisy. When the coordinated behavior of the individuals in the group is of interest, the GML is more fitted to account for the behavior.

More recently some authors have investigated behavior of individuals by programming metacontingencies, where a culturant composed by interlocking behavioral contingencies produces an aggregate product (an environmental effect) that is selected by consequences (Glenn et al., 2016). Vasconcelos and Todorov (2015) investigated the variability of coordinated behavior of pairs of individuals. The participants were required to play a computer game in which each individual in the pair took turns moving a playing piece. The game's objective was to position the two playing pieces in squares next to each other on a 64 square chessboard. The playing pieces could move in an L-move similar to the knight playing piece in a chess game. The experiment used an ABAB design, where no consequences were awarded in the A condition (extinction). Placing the playing pieces next to each other was awarded in the form of a message that said "Congratulations. You win!" in the B condition. The chessboard area where the participants would be awarded points for meeting decreased during condition B, first meetings in all 64 squares would be reinforced, the next phase reduced to 32 squares, the third phase reduced to 16 squares, and the fourth phase reduced to 4 squares. Vasconcelos and Todorov's results show that the number of moves and squares occupied while meeting were higher in conditions A compared to conditions B, demonstrating a clear effect of consequences on the two participants' coordinated behavior. The findings from Vasconcelos and Todorov (2015) were replicated and extended by de Carvalho et al. (2017) by adding additional measures of variability.

Recent studies have investigated the coordinated behavior of pairs (e.g., Lattal & Okouchi, 2023). Although concurrent schedules have been employed in some studies, most procedures and data of individuals were analyzed through the IFD paradigm (e.g., Gray, 1994) or did not fit participants' coordinated choices through the matching law (e.g., Borba et al., 2014; Vasconcelos & Todorov, 2015). This study aims to bridge the gap between experiments focusing on the behavior of individual participants and those examining the coordinated behavior of pairs. It seeks to evaluate whether variance in choice under concurrent schedules, where the reinforcement is contingent on the coordinated behavior of two individuals, would be a function of the obtained reinforcement ratio.

Method

Participants

Six students, one male and five females aged 18 – 27 accepted invitations to participate in this experiment. Participants were told that they would have to attend on three separate days and that the experiment would last between two and three hours each day. Thereafter, they were paired with each other subject to their availability. None of the students knew each other from before and had no prior knowledge of behavior analysis. The three pairs were given the names A1A2, B1B2 and C1C2. A1 indicates participant 1 in pair A, while A2 indicates participant 2 in pair A. Each participant made three visits to the laboratory, with each visit entitling them to a compensation of 250NOK (Norwegian krone), equivalent to about 27 dollars at the time of the experiment. This compensation was provided in the form of a universal gift card for each day attended, resulting in a total compensation of 750NOK for completing all three days.

Setting and Apparatus

The experimental sessions took place in a 2.5 m x 4 m room located at the department of behavioral sciences at Oslo Metropolitan University (OsloMet), Norway. The room was windowless and designed with two tables placed on opposite sides of a portable wall to prevent participants from seeing each other. Each table was equipped with an HP 24” monitor, a keyboard, and a chair. To suit the experimental design, the keyboards used in the experiment were modified standard computer keyboards. An HP EliteBook 830 G5 laptop was placed next to the tables and connected to the two monitors and keyboards. In participant 1’s keyboard the D-key were replaced with a left pointing arrow, and the G-key were replaced with a right pointing arrow, the remaining keys were physically removed. For participant 2, the H- and K-keys were replaced with arrows, the remaining keys were removed. The laptop was equipped with Xadrez version 2.11.6, a software designed in Visual Basic for Applications in Excel®, adapted from Vasconcelos and Todorov (2015). Figure 1 illustrates the experimental room.

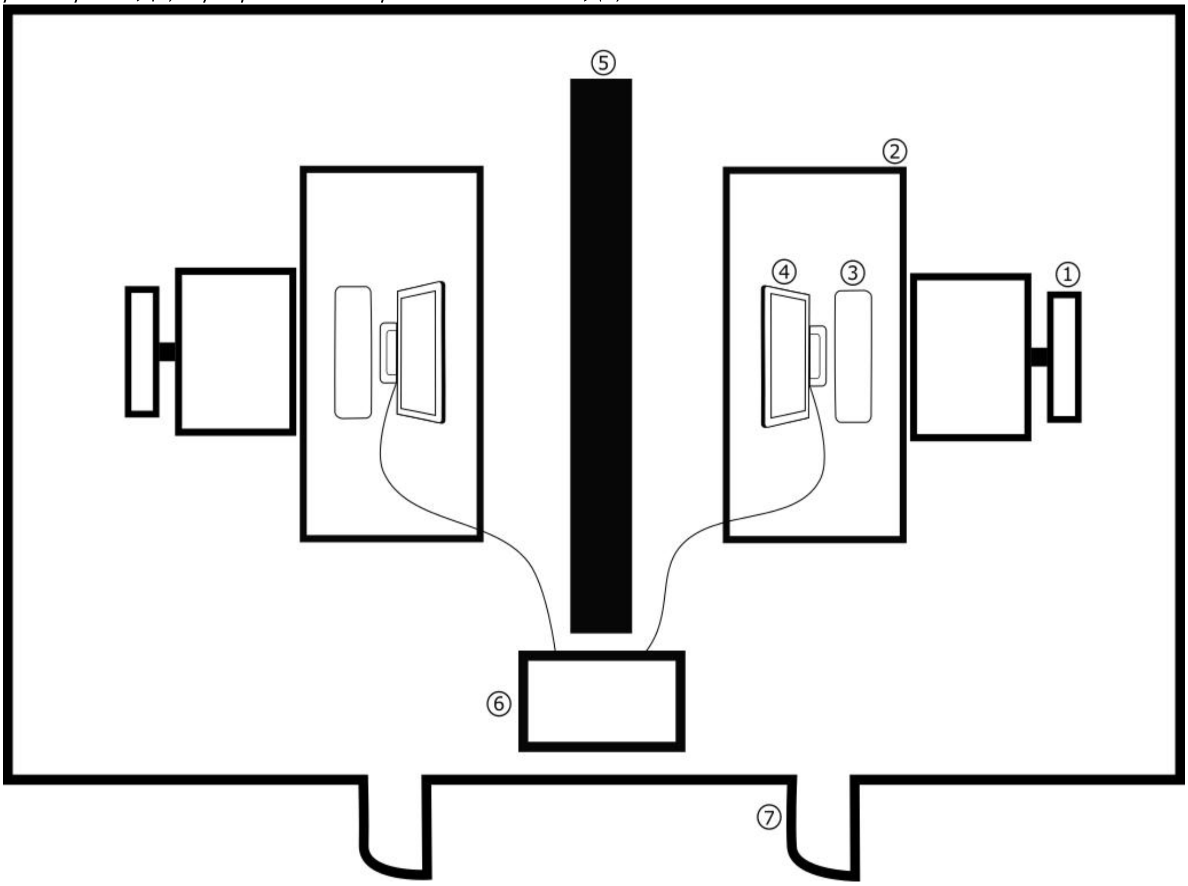
Procedure

Before starting the experiment, the participants were given a consent form to sign and provided with written instructions on how to play the game (see Appendix). The written instructions were available for the participants during the whole experiment. According to the Norwegian Center for Research Data (NSD) this experiment does not need approval from NSD.

The experimental task was displayed on the screen for the participants (see Figure 2), with two gray squares located next to each other in each of the screen’s top corners. Key 1 was on the left, Key 2 was on the right. The rest of the screen was black. The participants were instructed to place their playing pieces next to each other in one of the keys to make points. At the start of each trial, the playing pieces were placed next to each other at the bottom of the screen (Figure 2A), and the blue square indicated which playing piece could be moved. The participants alternated the first move in each trail, while also alternating the starting position of the yellow and red playing pieces. As seen in the example in Figure 2B, participant 1 controls the yellow playing piece and moves it to the left key. Participant 2 controls the red playing piece and places it next to the yellow playing piece, as seen in Figure 2C.

A coordinated response was recorded when the two playing pieces were positioned together in one of the two gray areas, with points delivered according to concurrent schedules of reinforcement with variable-interval schedules (VI). Contingent on the first coordinated response after the VI interval had elapsed, the message "Congratulations! 1 point" was displayed on the screen for three seconds (i.e., reinforcement). For coordinated responses before the end of the VI interval, no message was displayed. Following coordinated responses with no reinforcement, the playing pieces were automatically placed in their initial starting positions.

Figure 1
Illustration of the experimental room, seen from above. The room was 2.5 m x 4 m and had no windows. The room contained the following: (1) chairs, (2) tables, (3) keyboards, (4) monitors, (5) a 1,8 m tall wall to separate the participants, (6) laptop with the experiment software, (7) door.



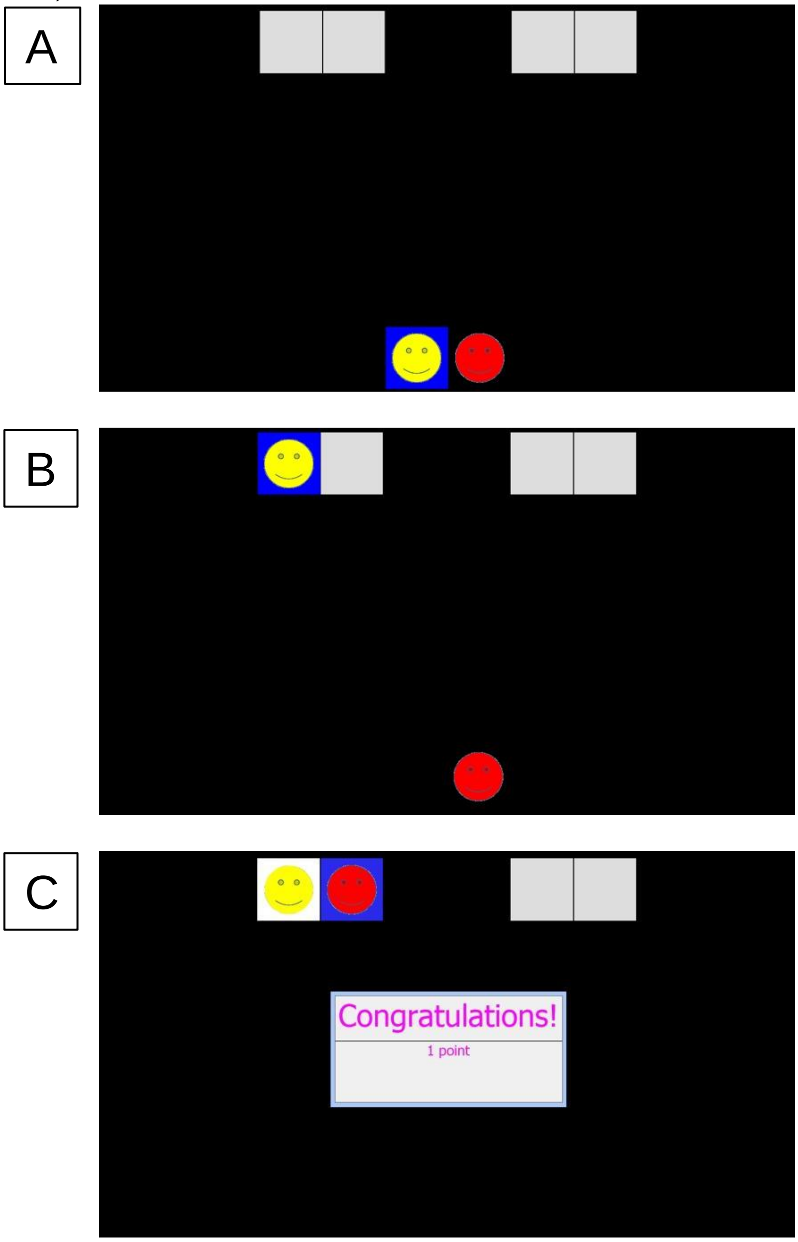
The pairs were informed that situating the two playing pieces in adjacent squares would conclude the current trial. Each trail would either end with the playing pieces reset to their original starting position or by the message "Congratulations! 1 point", as shown in Figure 2C, followed by the playing pieces reset to their original starting position. No other information regarding the criteria to get points was provided. However, the software was programmed so that if the first participant moved their piece to the left alternative, and the second participant moved to the right alternative, the first participant would be forced to move their playing piece to the right alternative in order to conclude the trail.

Each experimental session had a duration of seven minutes, with breaks between sessions lasting about two minutes. Participants had the option to request longer breaks of 10 - 15 minutes. Upon receiving the "end of round" message at the conclusion of each session, participants were instructed to knock on the door of the experimental room. Upon receiving this signal, the researcher would enter the room to inform the participants of their accumulated points for the session. During the experimental sessions, participants were prohibited from communicating with each other. Additionally, they were instructed to refrain from communicating with each other between the different days of participation.

Each phase continued for a minimum of ten sessions and until the relative rate of responses was stabilized. The relative rate of responses was calculated by dividing the number of responses on the left by the number of responses on the right. To meet the stability criterion, the most recent six sessions were considered, and the difference between the mean of the first three sessions and the last three sessions was calculated. The difference between the means was required to be less than 0.15. Because calculated means could lead to misleading stability (i.e., individual values in each mean could be apart, but producing means of than 0.15), individual log values for each phase were plotted in graph and deviations were spotted by visual inspection.

Figure 2

Illustration of the experimental task as shown for the participants. Panel A shows the starting position of both playing pieces. The blue square indicates whose turn it is to move. The two gray areas on the top of the screen are the left and right keys, where the participants could move their playing pieces. Panel B shows an example where participant 1 has moved their playing piece to the left key. Panel C shows that participant two has moved their playing piece next to participant 1. The meeting is registered as one coordinated response in the left key. If the meeting is reinforced, a message written "Congratulations! 1 point!" appeared in the middle of the screen before the playing pieces are reset to start, as seen in Panel A



Reinforcement Schedules and Change over Criterion

The experiment consisted of three phases for all three pairs. In the first phase all pairs were exposed to a 1:1 ratio concurrent schedule, in which both reinforcement schedules were VI 10 s. In the following two phases the pairs were exposed to 1:6 and 6:1 ratio concurrent schedule, with VI 10 s and VI 60 s schedules. The order of the three phases for each pair is presented in Table 1. The progression of the VI schedules contained 12 intervals and were calculated according to Fleshler and Hoffman (1962).

Table 1

The table gives an overview of the order of the conditions for the three pairs. The two last columns indicate the VI schedules on the left and the right alternative

Pair	Reinforcement Ratio	Left	Right
A1A2	1:1	VI 10	VI 10
	1:6	VI 10	VI 60
	6:1	VI 60	VI 10
B1B2	1:1	VI 10	VI 10
	6:1	VI 60	VI 10
	1:1	VI 10	VI 60
C1C2	1:1	VI 10	VI 10
	6:1	VI 60	VI 10
	1:6	VI 10	VI 60

In this experiment, a changeover delay (COD) of 3 seconds was implemented for each switching meeting. Specifically, this meant that the first coordinated response (meeting) made in one key after switching from the other key, would start an interval of 3-seconds delay, during which no coordinated responses would be reinforced.

Results

The response ratio was calculated by the number of coordinated responses on the left key divided by the number of coordinated responses on the right key for each session. Reinforcement ratios were calculated by the number of reinforcers obtained from the left key divided by the number of reinforcers obtained from the right key. Log transformed values of responses and reinforcement ratios were fitted into a least-squares linear regression. Figure 3 shows the log response ratio plotted against the log reinforcement ratio for all three pairs. Each data point represents one session. The last six sessions of each condition were included in the analysis. The regression line shows undermatching in two of the pairs, while the third pair shows insensitivity to reinforcement.

Figure 3 shows that the generalized matching law accounted for 0.945 and 0.836 of the variances for pairs A1A2 and B1B2 respectively. In contrast, for C1C2, the generalized matching law did not account for any variance with a value of 0.010. Additionally, the two first pairs' slope had sensitivity values of 0.583 and 0.391, while C1C2 had a value of 0.016, showing insensitivity to reinforcement. The three pairs showed no significant bias towards any of the alternatives (*y-intercept* -0.033, -0,007, -0,046 *for A1A2, B1B2 and C1C2, respectively*).

Table 2 presents the number of changeovers per session for each pair across the three experimental conditions. A changeover was counted whenever the dyads switched their meeting location from left to right or from right to left. A1A2 and B1B2 had a reduction of more than 50% in the number of changeovers from the first condition to the last two conditions. On the other hand, C1C2 showed a consistent number of changeovers throughout the experiment, indicating insensitivity to reinforcement. The stability of the pairs was reached within 10-18 sessions, with C1C2 reaching stability in the least number of sessions in each condition. These findings suggest that the participants in C1C2 might have responded the same way in all conditions, regardless of reinforcement contingencies.

The number of absolute responses varied across pairs and increased for all pairs, except for C1C2, when shifting from the first to the second condition. B1B2 showed a significant variation in the number of responses across sessions, with the lowest number of responses being 180 and the highest 4500. After the experiment, it was discovered that the participants held response keys, registering rapid responding. However, this pattern was only observed in five sessions, and the high number of responses did not affect the distribution of responses or the number of changeovers per session (Figure 4).

Figure 5 presents the log transformation of the individual response ratios for the final six sessions in each condition. While the behavior of the pair conforms to the GML, it's plausible that data from each individual may not conform to the GML. Each participant could distribute their responses differently, yet the total responses of the pair align with the GML. To isolate individual responses, we considered the participant who initiated the first move in each trial as having made the coordinated response. In each trail, the first participant moved their playing piece to one of the alternatives, and the second participant placed their playing piece next to participant one, following their lead. The data in Figure 5 suggests that the participants were under the control of each other's behavior, and the allocation of behavior were coordinated.

Figure 3

Data for all three pairs. Log ratio responses plotted against log ratio reinforcement.

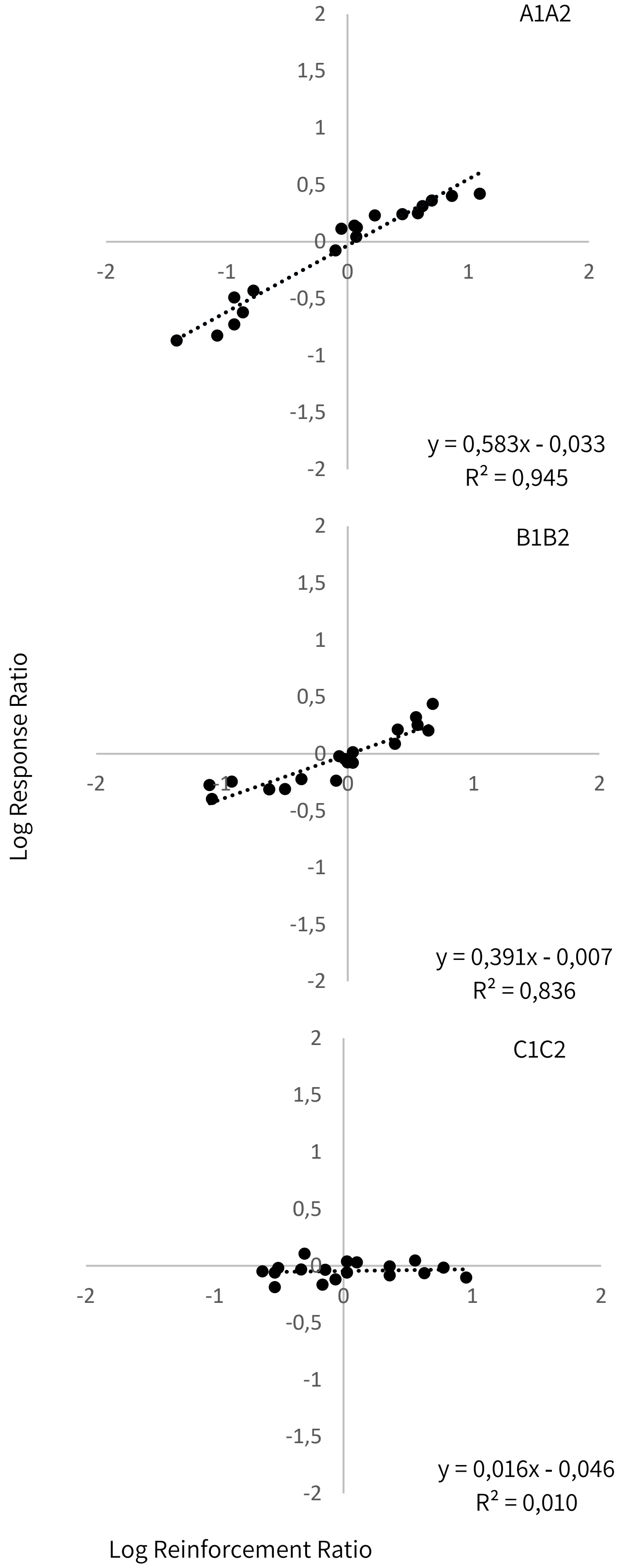


Table 2

The table shows the number of sessions until stability criterion and the mean number of change overs per condition for each of the pairs.

Pair	Reinforcement Ratio	Number of sessions until Stability	Mean CO per condition
A1A2	1:1	12	25
	1:6	12	10
	6:1	14	6
B1B2	1:1	13	44
	6:1	18	22
	1:1	15	21
C1C2	1:1	10	40
	6:1	11	35
	1:6	10	39

Figure 4

The absolute number of responses for each of the sessions, divided by condition. The y axis shows the number of responses, and the x axis sessions. Note that the y axis has different value for B1B2.

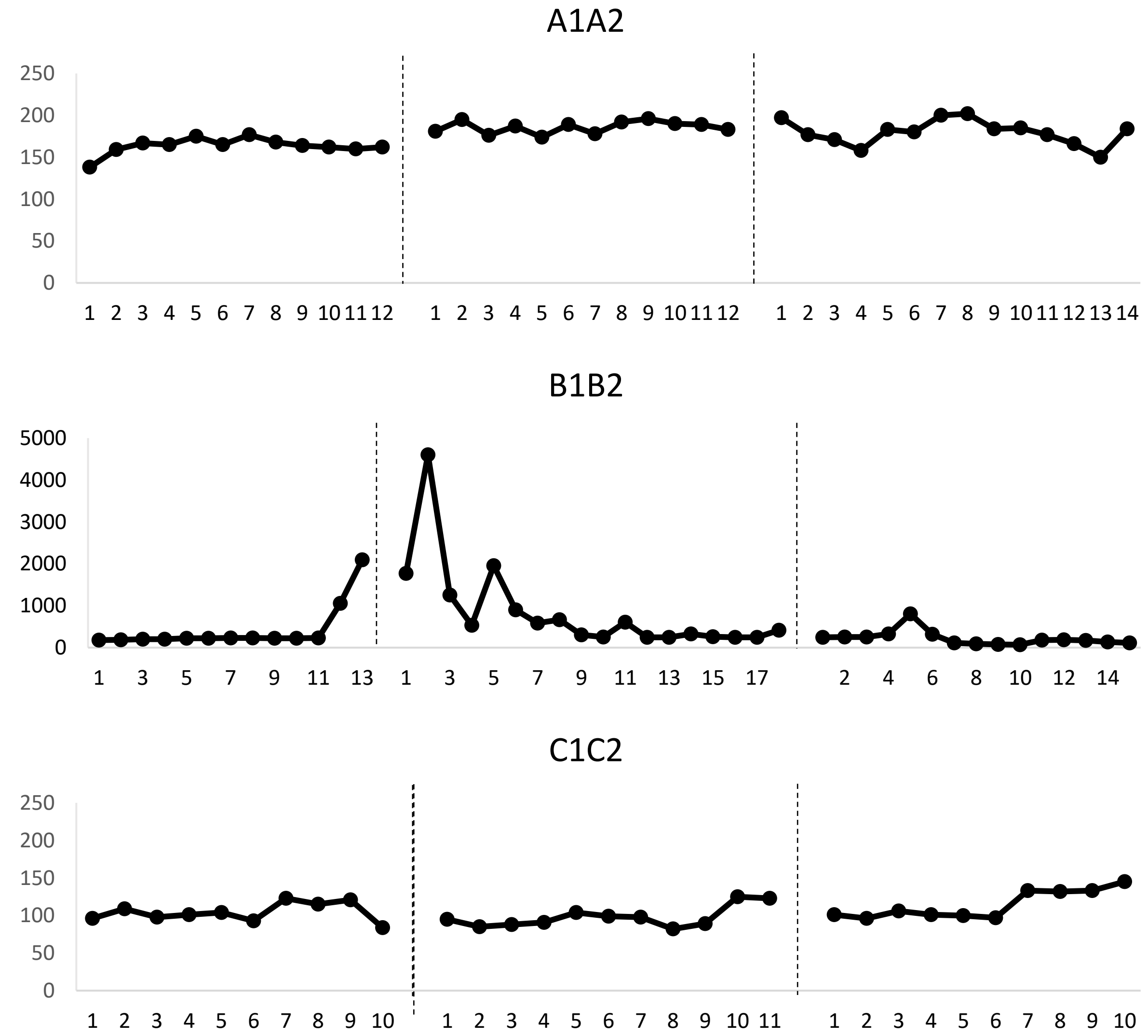
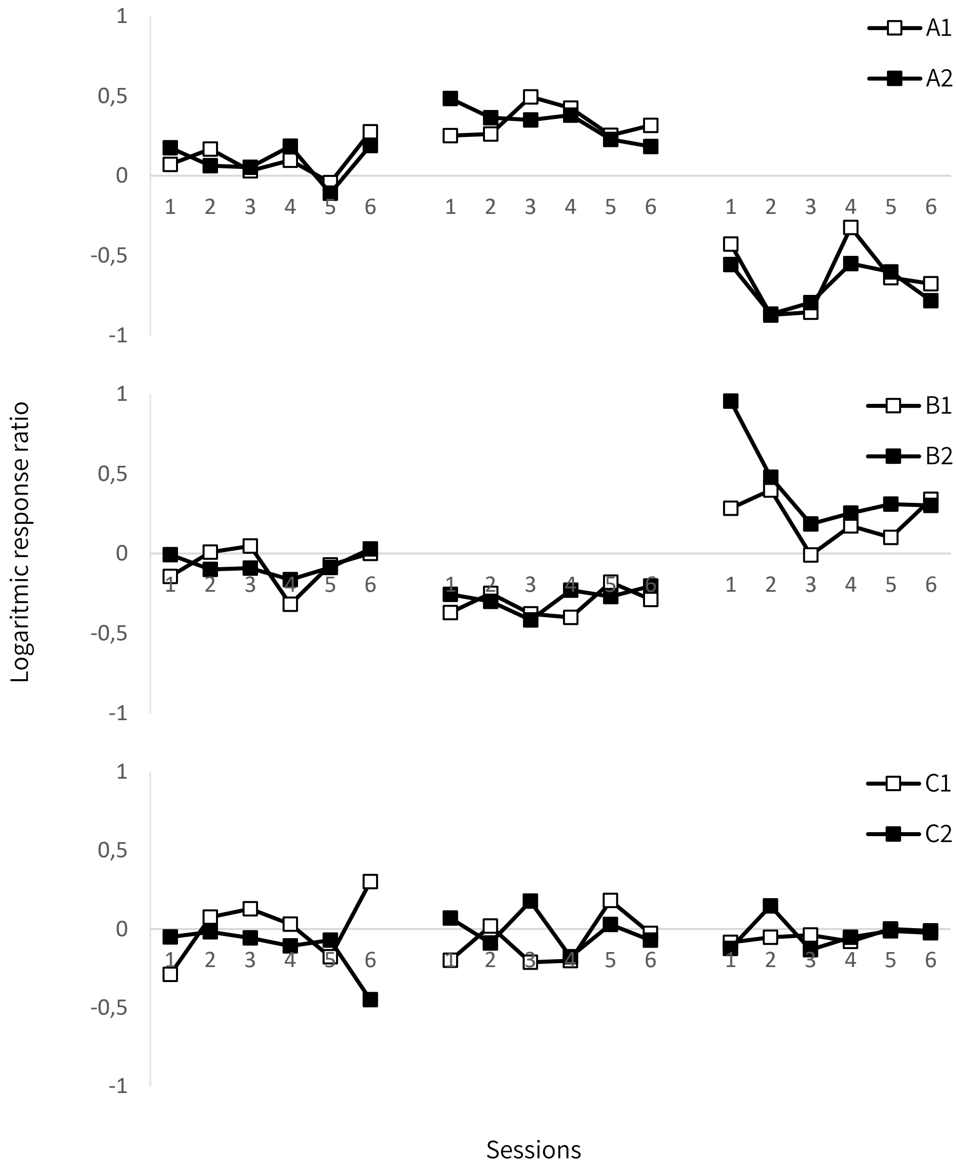


Figure 5

The log transformation of the individual response ratio, plotted by session. For each pair, the white square represents participant 1, and the black square represents participant 2. The y-axis represents the log transformation of the response ratio between the two alternatives. Values above zero represent the left key, and values below zero represents the right key.



Discussion

The aim of this research was to evaluate whether variance in choice under concurrent schedules whereby reinforcement is contingent on the coordinated behavior of two individuals would be a function of the obtained reinforcement ratio. The results presented in this paper illustrate that differences in the frequency of reinforcement over extended periods of time can have (pairs A1A2 and B1B2) a selective effect on the coordinated responses of individuals when they have a choice among two alternatives. Previous studies have illustrated how choice can be predicted by the availability of reinforcers for both humans (Horne & Lowe, 1993) and a variety of nonhuman species, such as pigeons (Herrnstein, 1961) and rats (Graft et al., 1977). Other studies on concurrent schedules of reinforcement investigated how the matching law predicts data from coordinated responses of more than one individual in an applied setting without experimental manipulations (Reed et al., 2006). In the present study, we expand on this body of knowledge showing how the generalized matching law may account for the distribution of coordinated responses of two individuals in an experimental controlled setting. Similarly to Vasconcelos and Todorov (2015), this study can be interpreted as a metacontingency analog: if coordinated responses are considered interlocking behavioral contingencies, distributions of meetings in the two keys are considered aggregate products, and programmed consequences are considered the receiving system.

Social Control

The results of the study revealed that all pairs of participants were also under social control of each other responses. As illustrated in Figure 5, both participants equally distributed their responses among the two alternatives. While it was possible for the two individuals to have distinct preferences, with one allocating more responses to the left and the other to the right alternative, the joint allocation of the pair's coordinated response would be a combination of their distinct preferences or tactics. However, no data indicated that the two participants had different preferences or tactics throughout the experiment. As shown in Figure 5, there were no instances of pairs that matched their coordinated responses, yet their individual responses were allocated differently. While pair C1C2 was not under the control of the reinforcement schedules, it is worth highlighting that both participants consistently displayed similar response patterns through the entire experiment. Neither C1 nor C2 diverged from their responses pattern in a manner that differed from their partner. This implies that the pair was under the control of each other's behavior.

Matching

The sensitivity value in the GML is a measurement of how much of the change of behavior is associated with the change in reinforcement. For pairs A1A2 and B1B2 the sensitivity values were 0.583 and 0.391 for each of the pairs, respectively. This result indicates that the response allocations of A1A2 and B1B2 were under the control of schedules of reinforcement. Whereas the behavior of C1C2 was insensitive to changes in the schedules of reinforcement with a sensitivity value of 0.016. Matching was observed when the pairs were subjected to both schedules of reinforcement and social control, indicating the strong influence of social control on coordinated responses.

Limitations and Further Research

The message "Congratulations! 1 point" was presented in the center of the screen, without specifying from which alternative the point was obtained. To improve future experiments, researchers should consider indicating which alternative the point was earned from, for example, by displaying the message on the same side of the screen as the point was made. This may aid in discriminating between the alternatives and could address the issue of insensitivity to reinforcement observed in C1C2. Additionally, it should not be possible to hold down the response button to make multiple responses in a row without the participants lifting the hand from the keyboard, as observed in some sessions with pair B1B2.

Future research should further explore the impact of leader-follower interactions on the distribution of coordinated responses, by examining whether a participant's response is influenced by the response distribution of their partner in a procedure where each participant is permitted to choose different keys at different times. To accomplish this, pairs could be allowed to move their playing pieces simultaneously but remain unaware of the other participant's move until both moves have been made. This type of adjustment may provide valuable insights into the coordination strategies employed by participants and how they adapt to the behavior of their partners.

Further experiments should scale up to include three or four members in each group, in order to further bridge the gap between individual matching law studies conducted in the laboratory, and studies which apply the matching law in natural settings involving the coordinated behavior of larger groups, such as football teams, class of students, or marketing team.

Conclusion

In conclusion, our findings suggest that when coordinating behavior under concurrent schedules, individuals are under the influence of at least two variables: (a) each other's responses, and (b) the schedules of reinforcement in force. We observed matching behavior in pairs A1A2 and B1B2 when both variables were in effect. However, pair C1C2 seemed to be solely under the influence of their partner's behavior and were insensitive to changes in the schedules of reinforcement. Prior research in this field has produced similar results between species as pigeons (e.g., Lattal & Okouchi, 2023; Velasco et al., 2017) and rats (de Carvalho et al., 2018). Thus, our study contributes by proposing a procedure to investigate coordination of responses in humans.

Appendix

Instructions

How to play:

1. Press any key to start the game.
2. You control the yellow playing piece. The other participant controls the red playing piece.
3. Pressing ⬅ will move your piece to the left; pressing ➡ will move your piece to the right.
4. The blue background color indicates who's turn it is to move.

The goal of the game:

1. Your goal is to make as many points as possible.
2. To get points, you have to meet the other player in one of the two marked areas. A meeting is achieved when both of your playing pieces are placed in squares next to each other.
3. After some meetings you get the message "Congratulation, 1 point!", followed by the pieces being reset to the starting positions, and after some meetings, your pieces will be reset to the start position without any points.
4. Use both highlighted areas to optimize gains
5. The more meetings, the higher is your possibility to earn points (more meetings = more points).

General information:

1. You will improve your performance simply by playing the game.
2. If you have any questions after reading these or the following instructions, please ask the researcher supervising the study before you begin.
3. The session is over when you see the message **"End".**
4. You are not allowed to communicate during the experimental sessions.
5. During breaks, you can talk, but you are not allowed to discuss the experiment.
6. After each session is finished, the supervising researcher will inform you about how many points you have earned.

If you have any questions about the instructions, please ask the researcher before you begin.

Declaration of conflict of interest

The author declares that there is no conflict of interest regarding the publication of this article.

Contributions from Authors

The contribution of each author can be attributed as follows: F. D., L. C. C. and K. C. C. developed the conceptual framework and formulated the method. F. D. and K. C. C. collected and analyzed the data. FD did the first draft of the paper. FD, FHB and KCC were responsible for the final draft.

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