

# Diachronic collaboration yields adaptive problem solving

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Teamwork is considered effective when the team accomplishes something together that the members of the team could not have on their own. But what makes for effective teamwork? This research investigates the effect of team structure on the problem solving abilities of teams. A common way to organize or structure teamwork is to break big problems into smaller problems that can be divided among the members of the team and worked on independently. Though team members are working independently, they are all working at the same time, and this type of teamwork can be called synchronic collaboration. In contrast, diachronic collaboration involves team members working one at a time on the same problem, each building upon the previous solution. Wikipedia article writing is an example of diachronic collaboration. Most real world collaborations have both synchronic and diachronic elements, which makes it difficult to assess the relative effectiveness of each type of collaboration. The experiments outlined below are designed to measure the problem solving capacities of teams organized either diachronically or synchronically. My hypothesis is that organizing teamwork diachronically will make teams more effective at utilizing feedback to solve problems, also known as adaptive problem solving.

Adaptive problem solving is changing or adapting a solution in response to feedback. Adaptive problems are pervasive in the history of human culture and its evolution, in particular the evolution of technology. Culturally we uphold certain inventors as heroes having created artifacts and ideas without precedent or precursor, when in fact the historical evidence favors an alternative view: Technological progress does not advance by leaps and bounds, but by many small steps and incremental improvements. One conclusion that can be drawn from this evidence is that it is easier to adapt and incrementally improve an existing artifact than to create one from scratch. However, this continuity may only exist when looking across years and generations of human history. This research for the first time compares diachronic and synchronic collaboration as techniques for solving problems in the same time frame. If teams organized diachronically are more effective at solving adaptive problems, it suggests that the tools and abilities that allow and facilitate diachronic collaboration—e.g., having a way to inherit and modify past solutions—are more important factors in explaining the evolution of technology than accounting for the ingenuity of individuals.

## Design

Table 1: Overview of experiments and conditions. All manipulations are between team.

#	Experiment	Team structure	Problem	Feedback
0	Pilot	solo	adaptive, insight	yes
1	Team structure	diachronic, synchronic	adaptive	yes
2	Feedback	diachronic, synchronic	adaptive	no, enforce
3	Insight problem	diachronic, synchronic	insight	
4	Multiple problems	diachronic, synchronic	multiple adaptive	yes

The experiments are designed to reveal the conditions under which diachronic collaboration is more effective than synchronic collaboration. Participants are randomly assigned into teams and given a problem to solve in a fixed amount of time. The purpose of the Pilot Experiment is to calibrate the difficulty of the problems used in the main experiments to be difficult enough to warrant teamwork, but not impossible for the average participant to succeed given enough time. Experiment 1 investigates the effect of team structure on solving adaptive problems, with the prediction that diachronic collaboration will be more effective than synchronic collaboration. To investigate whether this difference might be due to responsiveness to feedback,

in Experiment 2 the feedback made available to the teams is manipulated, either removing it completely or enforcing it such that team performance is only allowed to improve. Removing feedback is predicted to impair diachronic more than synchronic performance, and enforcing feedback should improve synchronic more than diachronic performance. Experiment 3 tests the impact of team structure on solving insight problems. Unlike adaptive problems, for insight problems feedback is generally unhelpful, as there is no gradation between partial and whole solutions. In solving insight problems, diachronic collaboration is no longer predicted to be more effective than synchronic collaboration, because informative feedback is not available. The final Experiment 4 is an extension of Experiment 1 that addresses the discrepancy between calendar hours and labor hours in the team structure manipulation by having teams complete four problems in the same number of calendar hours.

## 1 Team structure

Experiment 1 is designed to test the hypothesis that diachronic collaboration is more effective than synchronic collaboration at solving adaptive problems. The type of adaptive problems solved by teams in Experiment 1 are classification problems. The solution to a classification problem involves generating predicted labels for unlabeled data using statistics and machine learning to improve the accuracy of the predictions. For example, a typical classification problem is to predict whether or not passengers on the Titanic survived based on their age, gender, ticket price, cabin location, and other features of the passenger. Classification problems are good examples of adaptive problems because there are many possible solutions, all varying in degree of success. For example, teams can use decision trees, linear regression, neural network models, and combinations of these, each varying in which features they are trained on and the parameters of the models. Given the vast space of possible solutions, a useful strategy for solving classification problems is to iteratively try out different solutions and incrementally improve classification accuracy. Although both diachronic and synchronic teams are able to iteratively develop solutions to classification problems, diachronic teams are hypothesized to be more effective than synchronic teams at utilizing this feedback to improve classification accuracy.

**Procedure.** Skilled and motivated participants are randomly assigned team and condition. Each team is given training data and instructed to write a program that accepts unlabeled test data and generates predicted labels. Synchronic teams are given two hours with all four team members in the same room. Each team member is provided a personal work station and network access to the team's program files, but there are no constraints on how the members of the synchronic teams interact or delegate labor over the course of the two hours. Diachronic teams work one at a time, each spending two hours on the program, and are not allowed to interact with their whole team all at once. For diachronic teams, only a single workstation is needed. Team members can at any time submit their program for evaluation against the test data, and receive feedback in the form of a classification accuracy score. After eight labor hours have been spent by each team, the final version of each team's program is submitted and evaluated. The primary hypothesis tested in Experiment 1 is that diachronic teams will produce more accurate predictions than synchronic teams.

### Is it worth it to work in teams on this problem?

In order to interpret the impact of team structure on team performance, it's important to confirm that the task being performed is one that benefits from teamwork. This analysis is done by comparing overall team performance to performance on the same problem for the same amount of time by an individual with equal skill and motivation working alone. Teams are predicted to outperform individuals on classification problems.

### Are diachronic teams more effective adaptive problem solvers?

The primary hypothesis tested in Experiment 1 is that diachronic collaboration will be more effective than synchronic collaborations at solving adaptive problems. Problem solving effectiveness is measured in terms of

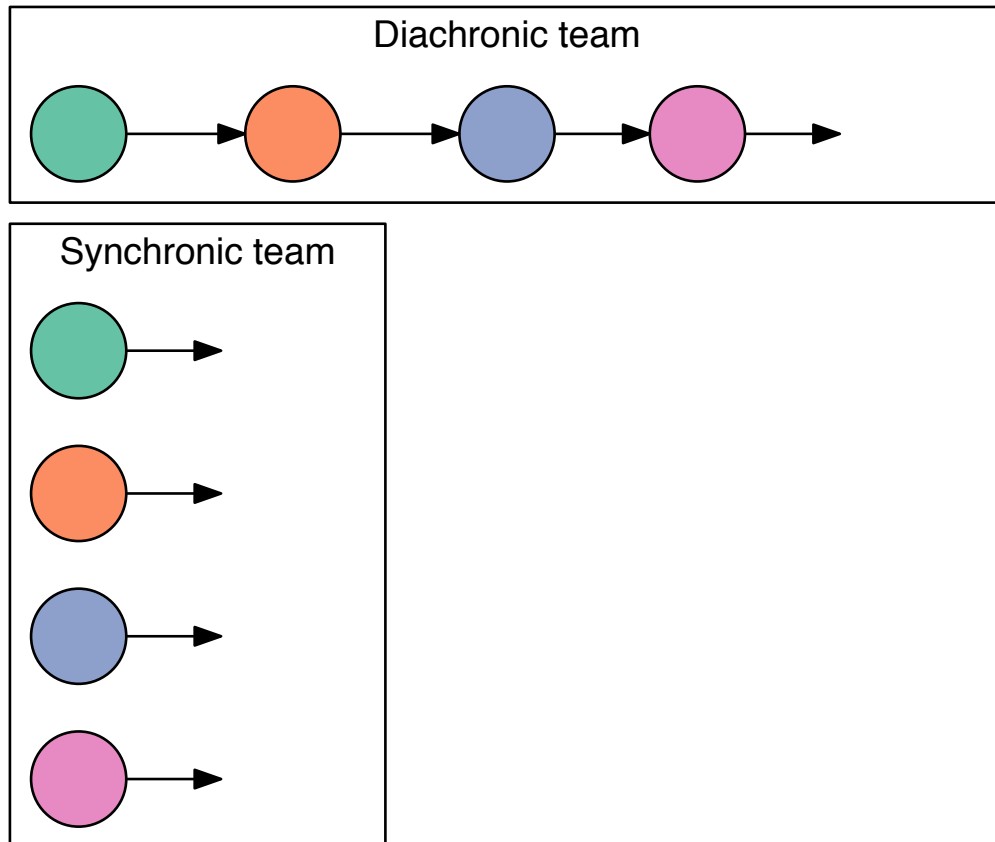


Figure 1: Team structures. Teams of four are allotted the same number of total labor hours to solve a problem. Synchronic teams work all at the same time on a single solution. Diachronic teams work one at a time, each inheriting the previous solution and improving it.

the classification accuracy of the team's final submission. Participants are equally skilled and motivated which case a difference in team performance can be attributed to the structure of the team's interaction.

## Do diachronic teams make more submissions?

The primary reason diachronic teams are expected to outperform synchronic teams is because they are better able to utilize feedback and iteratively improve solutions. If this is true, we should expect to see diachronic teams make more submissions (and thus receive more feedback) than synchronic teams.

Part of the reason diachronic teams may make more submissions reflects the fact that a team's submission rate may be more dependent on calendar hours than on labor hours. If controlling for submission rate by calendar hours still reveals a difference in submissions for diachronic and synchronic teams, then part of the reason diachronic teams are better able to utilize feedback may be because they are able to engage in a faster development cycle.

## 2 Feedback

In Experiment 2, the feedback made available to teams about their performance is altered in order to test the hypothesis that the effectiveness of diachronic collaboration in solving adaptive problems depends on reliable sources of feedback. In the first condition, feedback is removed completely, and teams do not know for certain their performance until the end of the experiment. Removing feedback is expected to impair diachronic more than synchronic team performance. In the second condition, feedback is enforced such that a team members contributions can only be shared with the rest of the team if that contribution measurably improves team performance. If diachronic teams are already using feedback to incrementally improve team performance, enforcing feedback should only help synchronic teams by encouraging them to focus on incremental improvements in team performance.

**Procedure.** Teams in Experiment 2 are assigned to either the no feedback condition or the enforced feedback position. In the no feedback condition, diachronic and synchronic teams are no longer able to submit their programs for evaluation prior to the end of the experiment. In the enforced feedback condition, every time a team member commits a change to the team's program files, the program is evaluated against the test data. If the contribution does not improve past team performance, it is rejected, and subject to further editing. Otherwise, the contribution is distributed to the other members of the team.

## Do diachronic teams depend on feedback?

If the adaptive problem solving abilities of diachronic teams are due to increased responsiveness to feedback, then removing feedback should impair diachronic team performance relative to synchronic team performance.

## Does enforcing feedback improve synchronic performance?

If the reason synchronic teams are outperformed by diachronic teams is that they aren't utilizing feedback as effectively, enforcing feedback so that team performance must improve through all changes to the team's solution should improve synchronic team performance more than diachronic team performance.

## 3 Insight problem

Not all problems are adaptive problems. Where adaptive problems have many possible solutions, all varying in degree of success, insight problems have only one solution; they are either solved or not. Experiment 3

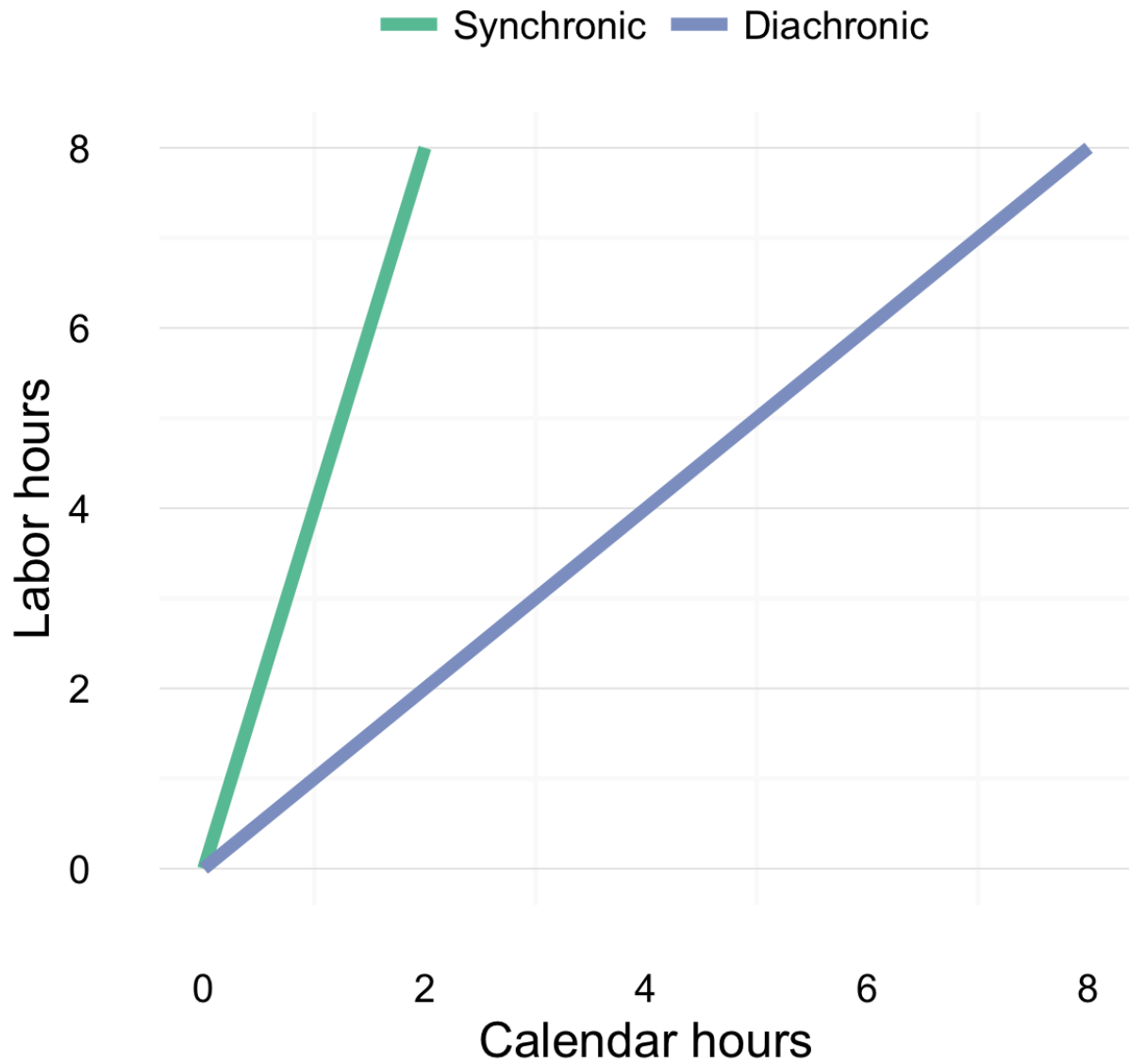


Figure 2: Calendar and labor hours. Teams are allotted 8 total labor hours. Synchronic teams of four use all 8 labor hours in the first 2 calendar hours. Diachronic teams spread out their labor hours over 8 calendar hours.

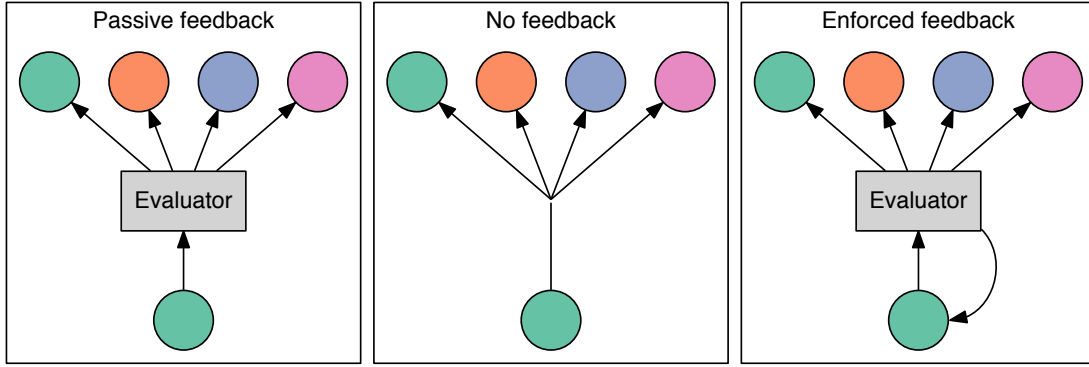
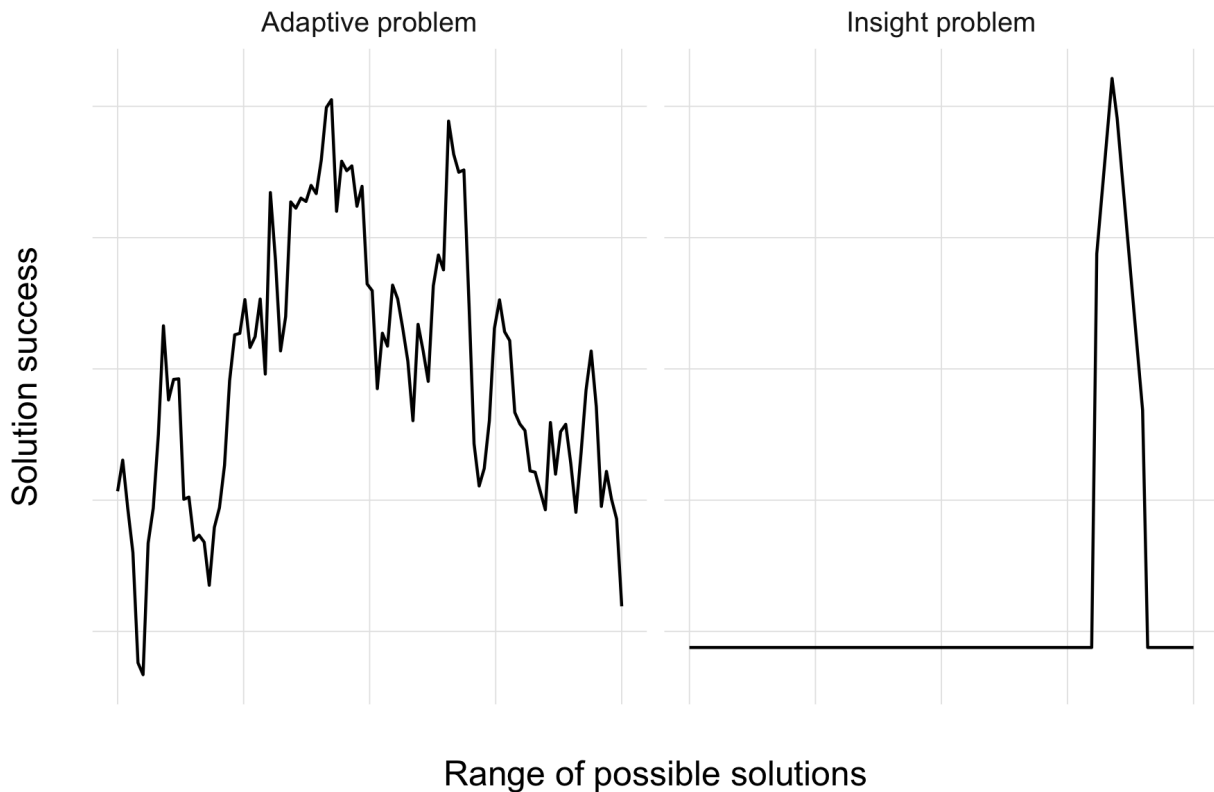


Figure 3: Feedback mechanisms. When feedback is provided (\*\*left\*\*), changes in team performance are made available to the team after submitting the program for evaluation. This is the feedback condition used in Experiment 1. Experiment 2 included two other feedback conditions. Feedback is either removed (\*\*middle\*\*) or enforced (\*\*right\*\*) such that contributions that do not improve team performance are rejected and cannot be shared with the members of the team.

investigates the effect of team structure on solving insight problems. Because feedback is unhelpful, diachronic teams do not have an advantage in being able to incrementally improve solutions. For teamwork to be helpful in solving an insight problem, everyone in a team should search for the solution in parallel. This type of problem solving is hypothesized to be better equipped for synchronic collaboration.



The insight problems in Experiment 3 are similarly data-oriented to facilitate comparison across experiments. Participants with the same skills and motivation compete in a “Draw my data” contest. In this contest, teams are given artificial data and asked to identify the object who’s image is contained hidden within the data. Solving this problem requires searching through the many variables of the data (most of them irrelevant) and visualizing various combinations until the correct view of the data is discovered. Discovering the object that was “drawn” in the data is the moment of insight that solves the problem.

**Procedure.** Teams complete as many “Draw my data” problems as they can in 8 labor hours, organized synchronically or diachronically. Solutions are submitted by naming the object in the data. If correct, teams receive another dataset. The code used to generate the visualizations and the plots themselves are shared among the members of the team.

### Do insight problems benefit from teamwork?

Before the effect of team structure on performance can be interpreted, the effectiveness of teamwork in solving insight problems first needs to be demonstrated. Teams are expected to complete insight problems at a faster rate than individuals working alone.

### Do synchronic teams excel at insight problems?

Without feedback to guide iteration and change, diachronic teams no longer have an advantage over synchronic teams when solving insight problems. Synchronic teams are expected to outperform diachronic teams because they are better able to coordinate search for the solution in parallel.

## 4 Multiple problems

The purpose of Experiment 4 is to replicate Experiment 1 and extend it to include teams solving multiple adaptive problems over the same number of calendar hours. In Experiment 1, synchronic teams completed their task in 2 calendar hours, where diachronic teams required 8. Even if diachronic teams outperformed synchronic teams, synchronic collaboration may still be seen as effective because they completed the task sooner. In Experiment 4, the conclusions of Experiment 1 are tested in conditions where teams of four complete four different problems in either diachronic or synchronic teams over the same 8 calendar hour time frame.

**Procedure.** Experiment 4 is conducted like Experiment 1, except both teams now compete for 8 hours.

### Do the results extend to multiple problems?

The predicted results for Experiment 4 are that diachronic teams will outperform synchronic teams across multiple problems.

### Do teams get more efficient?

Participants in Experiment 4 work on four different problems in a row. Do they get better at solving adaptive problems?

## Summary

These experiments are designed to reveal the problem solving capacities of teams organized either diachronically or synchronically. The purpose of this investigation is not to prescribe certain team structures over others, since it seems likely that the most effective teams have elements of both team structures, but to outline the conditions for which diachronic collaboration is most effective. Diachronic collaboration is hypothesized to be most effective in solving problems that can be adapted in response to feedback. Since adaptive problem solving forms the basis for technological evolution, these results suggest that the methods and mechanisms that allow for diachronic collaboration might be critical to explaining the evolution of our species.





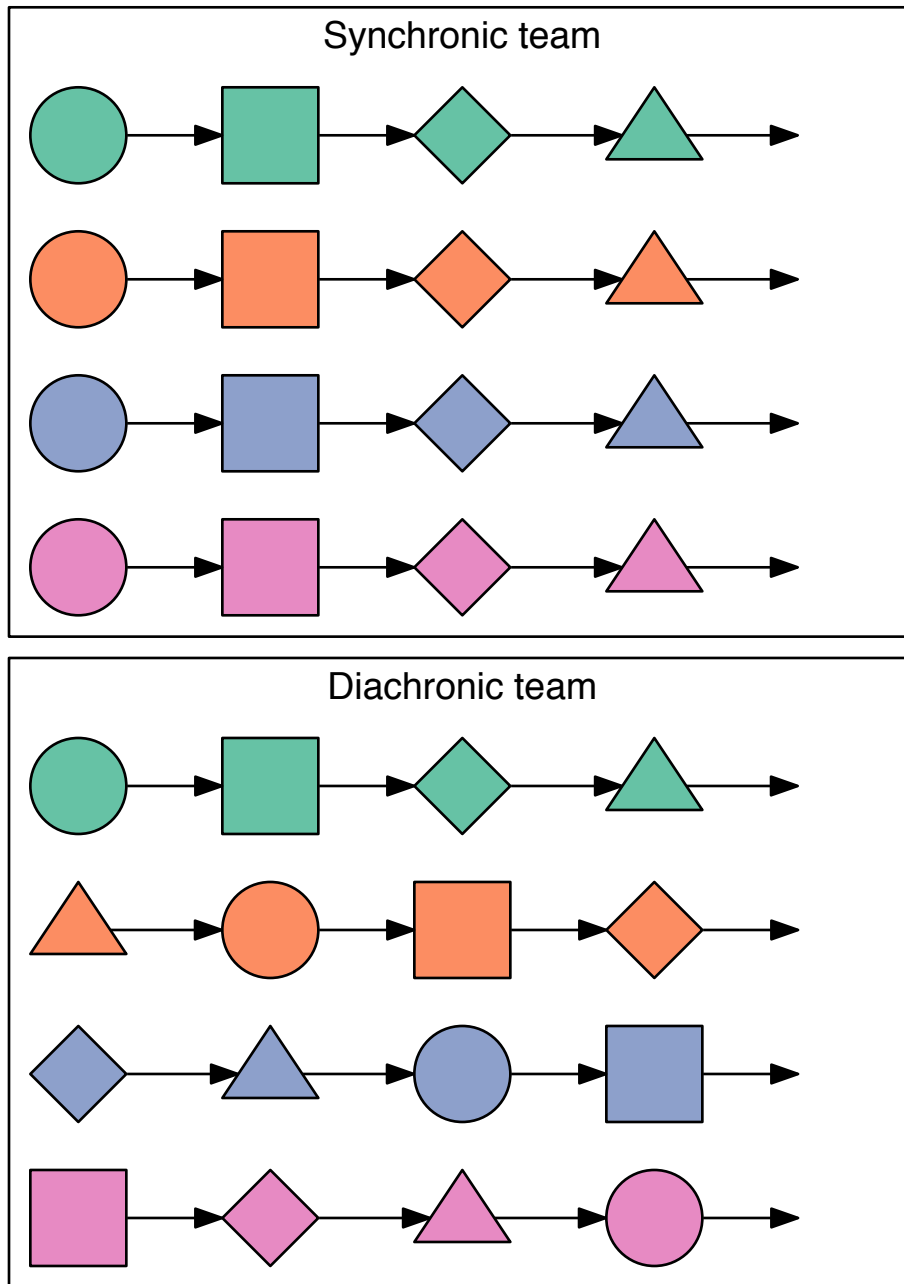


Figure 4: Two ways of allocating the same number of calendar hours toward multiple projects. In synchronic teams, team members work on each project from beginning to end in lockstep. In diachronic teams, team members work on different projects at the same time, and collaborate over time.