CHAPTER 4—RESPONSE PATTERNS

For the coordination class construct to be useful, features of student response patterns must appear plausible when viewed from a coordination class perspective. Response patterns from 646 students are presented here. Student samples are separated into two groups, described as Less Technical (LT) and More Technical (MT), depending on the course from which they were drawn; section 4.1 begins with a description of each student sample. Task administration procedures are also described in section 4.1. Response data are presented in section 4.2, with emphasis on the features of animations popular and unpopular with students from each group. The response data raise a number of issues related to the coordination class analysis to be pursued in later chapters. The chapter concludes with a discussion of several of these issues.

4.1 SAMPLES AND PROCEDURES

Student samples and the procedures used for gathering responses to the four tasks from each set of students are described in this section. Two sets of procedures were used in the study, those for large groups of students in a large classroom (listed as "lectures" in Table 4.1) and those for individual students (listed as "interviews"). Among the differences in procedure were that students in large classrooms were shown the animations a limited number of times in a particular order before making decisions, while students in interviews were allowed to view animations within a set repeatedly and in any order. Details, including variations within the large classroom and interview procedures for different sets of students, are provided below.

4.1.1 Samples

As shown in Table 4.1, students in two sets of interviews and in five different lecture classrooms completed the tasks. Subjects in the Less Technical group were drawn from psychology courses and an algebra-based physics course. Subjects in the More Technical group were drawn from calculus-based physics courses. All subjects were students at the University of Massachusetts-Amherst at the time of their participation.

Group	**Subgroup**	**Responses**
(LT) Less Technical	Psychology (Educational Psychology lecture)	130
	Health Science (Algebra-based Physics lecture)	173
(MT) More Technical	Engineering A (Calculus-based Physics lecture)	70
	Engineering B (Calculus-based Physics lecture)	171
	Majors (Calculus-based Physics lecture)	52
LT	Psychology (interviews)	26
MT	Honors Engineering (interviews)	24
LT Group Total		*329*
MT Group Total		*317*
Grand Total		**646**

Table 4.1 Complete responses gathered from each set of students.

Students included in the educational psychology lecture sample answered demographic questions, completed all parts of the tasks, and indicated that they had not previously seen the two-tracks demonstrations. Fifty one of the students had never taken a physics class, 69 reported taking at least one semester of physics in secondary school, and 22 reported having taken at least one semester of physics in college. One hundred of the students were female and 30 were male. Fifteen participants classified themselves as freshmen, 53 as sophomores, 34 as juniors, 26 as seniors, and 2 as graduate students.

Physics 132 is the second semester of the algebra-based 131/132 sequence, taken by pre-medical students and those majoring in other fields related to health science. Although students from a wide variety of majors, not all related to health science, take the course, this is referred to as the Health Science group. The Health Science group was split approximately evenly by gender. The projector used in the Health Scientists' course was dim, making it difficult to see the ball clearly in the flat-valley animations from some seats in the lecture hall. Animations for the V-valley tracks were clear.

Physics 151 is the first semester of the calculus-based 151/152 sequence for scientists and engineers. This is labeled the Engineers' course, although students from a variety of majors take the course. The tasks were administered in two sections of the Engineers' course, referred to here as A and B. Physics 172, labeled the Majors' course is the second semester of the calculus-based 171/172 introductory sequence taken by physics majors. Students in section A of the Engineers' course completed the tasks during the first week of the semester, before any physics content had been covered. Several weeks before completing the animated one-ball vs. two-ball tasks for this experiment, the majority of subjects from section B of the Engineers' course had completed a static (strobe diagram) version of the one-ball vs. two-ball task. In each section of a calculus-based physics course, approximately 75% of respondents were male.

At the time of the task administration, the two-tracks demonstration had not been used in any of the physics courses from which students were drawn, and it had not been used in the previous semester of either the Health Scientists' or the Majors' sequence. Students in section A of the Engineers' course had not encountered, at least in a post-secondary physics course, any of the physics content necessary for analyzing the two-tracks situations. Students in the other three sections had completed units covering kinematics, Newton's laws, and conservation of energy either in their current semester (in the case of section B of the Engineers' course) or in a previous semester (in the case of the Health Scientists' and the Majors' courses.) These units include an array of concepts that could be used to analyze motion in the two-tracks situations.

Nineteen males and five females from the honors section of the first semester calculus-based physics course volunteered to be interviewed. This was the honors section of the Engineers' course, described above. All interviews took place late in the semester, after the students had studied kinematics, Newton's laws, and conservation of energy. Six males and twenty females taking a psychology course volunteered to be interviewed. Twenty psychology students had completed at least one semester of physics in either high school or college, and six had not. Two additional physics interviews and one psychology interview are not included in the data set because the students involved had previously seen the two-tracks demonstration in a physics course.

4.1.2 Large classroom procedures

For each set of students, the two-tracks apparatuses were described first. Either the actual apparatuses were shown, with no balls available for rolling, or a picture of each apparatus was displayed using an overhead projector. The presenter pointed out that the two tracks in each apparatus had the same beginning height and the same ending height, and that the tracks and balls were made of metal. Students were told that they would be shown several computer animations of balls rolling on each apparatus, and asked to identify the animations depicting motion most like what real metal balls would do on the real tracks. Choices for most realistic animation were gathered for the four sets of animations in the following order: one-ball flat-valley, one-ball V-valley, two-ball flat-valley, and two-ball V-valley.

In the large classroom administrations of the tasks, computer animations were projected on a screen at the front of a lecture hall. Within a set, each of the five animations was played at the regular speed first. After they had all been played, the slow speed animation was played for all five, and then the regular speed animation was played again for all five motions. Students responded individually, with an electronic classroom communication system in some classes and bubble sheets in others. This procedure took approximately fifteen minutes. Demographic information was collected from the educational psychology students.

Psychology student participants received research participation credit. Students in physics classes were not compensated for their participation in the study. The author and four physics professors presented the tasks to large lecture classes.

4.1.3 Interview procedures

Interviews were semi-structured and open-ended. The introduction to the interview tasks was similar to that for the large lecture tasks, using a picture of each demonstration apparatus to describe its features. After describing the first task, the interviewer pointed out controls for the animations and demonstrated their use. Students were given a chance to ask questions, and were then given control of the computer. Students were encouraged to think aloud as they looked through the computer animations and made their decisions.

In contrast to the large classroom procedure, where the presenter controlled the order and pace of animation viewing, interviewed students could run animations within a set (for example, the one-ball flat-valley set of animations) as many times as they liked and in any order. They were provided with no physical resources for record keeping, although interviewers occasionally helped students keep track of which animations they had ruled out. Students were not allowed to change responses after moving on to a new set of animations.

Students were asked, either during the process of making decisions or afterward, to explain their reasons for choosing or rejecting particular computer animations. Because too much thinking out loud could distract some students, interviewers made judgments for each student about how much to prod for reasoning. A rule of thumb was that the student should have indicated reasons for (a) ruling out four of the five animations as less realistic than the fifth, or (b) "ruling in" one of the five animations as realistic. Interviewers were careful not to indicate whether student reasoning was correct or incorrect. Students were often asked to provide a description of, repeat, or elaborate on their reasoning about particular animations.

Physics students (from the honors section of the Engineering course) received nominal monetary compensation for their participation, and psychology student interviewees received research participation credit. The author and two physics professors conducted interviews with physics students, and a senior undergraduate physics major conducted interviews with psychology students.

Interviewers took brief notes about each student's decision-making and recorded the final choice for each task. Only these notes are available for the first twelve physics student interviews; the twelve subsequent physics student interviews, and twenty four of the twenty six psychology student interviews, were recorded on audio tape and transcribed.

4.2 FINDINGS

The purposes of this section are to present response patterns and to point out some issues related to coordination classes. Emphasis is placed on animation features and comparisons between one-ball and two-ball response patterns for the LT and MT groups. Discussed in particular detail are the fractions of students from each group choosing animations in which two balls reach the ends of their tracks simultaneously. The final sub-section points to several issues to be addressed in later chapters with the coordination class analysis of interview transcripts.

4.2.1 Flat-valley response patterns

Response patterns for the flat-valley tasks, for Less Technical and More Technical students, are presented in Figure 4.1. To facilitate the making of connections between computer animation features and student choices, a chart of selected unrealistic features for each flat-valley animations is provided in Table 4.2. Qualitatively unrealistic speed changes (for instance, accelerations with unrealistic directions) are included in Table 4.2. Accelerations with realistic directions but unrealistic magnitudes (for instance, the small magnitude of the acceleration on the final slope in the [sl] animation) are excluded from the chart. With the exception of race results, one-ball and two-ball flat-valley animations with the same label contain the same deviations from realistic motion.

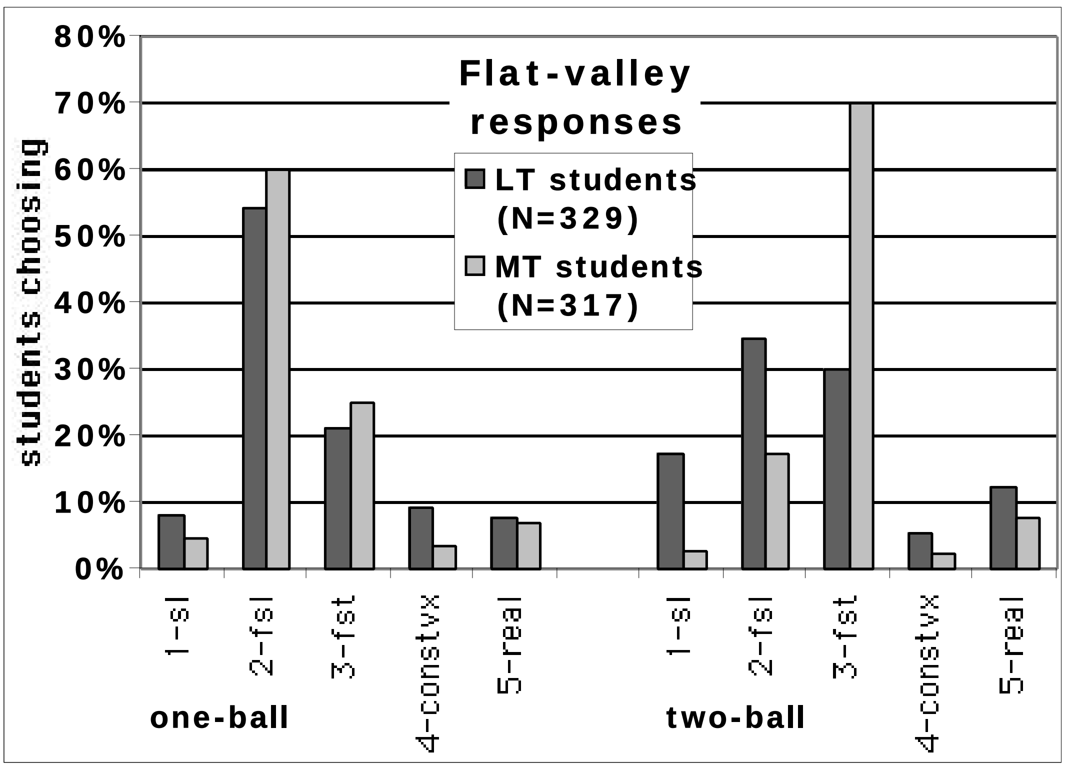

Figure 4.1 Responses to one-ball and two-ball flat-valley tasks.

As shown in Figure 4.1, the [fsl] and [fst] motions were much more popular than the other three motions in the one-ball flat-valley task, with [fsl] much more popular than [fst]. LT and MT response patterns were similar for the one-ball task. In the two-ball task, the same two animations were popular, but the number of students choosing each is roughly reversed from the one-ball task. In contrast to the LT response pattern, the two-ball response pattern for MT students is highly peaked on the [fst] animation.

Flat-valley motion	**1-sl**	**2-fsl**	**3-fst**	**4-constvx**	**5-real**
One-ball task, percent of all students choosing	7%	57%	23%	6%	7%
Two-ball task, percent of all students choosing	10%	26%	50%	4%	10%
Deviations observable in one-ball and two-ball animations					
Speed fails to increase on second slope	X			X	
Speed fails to decrease on final slope				X	
Speed decreases on valley floor		X	X		
Sudden speed increase, beginning of final shelf			X		
Slower on final shelf than on initial shelf	X	X			
Deviations observable only in two-ball animations					
Ball A wins race	X	X			
Balls A and B tie			X	X	

Table 4.2 Selected deviations from realistic motion: flat-valley animations.

As shown in Table 4.2, the only feature unique to the consistently popular flat-valley motions ([fsl] and [fst]) is that the speed of ball B decreases as it rolls across the valley floor. The popular motions also depict increasing speed when ball B rolls down the second slope and decreasing speed when it rolls up the final slope, but they share these features with the consistently unpopular [real] motion. In the two-ball flat-valley task, the two "tying" animations were identified as realistic by very different numbers of students. Similarly, [fsl] was much more popular than [sl], even though the two animations showed ball A winning the race.

4.2.2 V-valley response patterns

Response patterns for the V-valley tasks are presented in Figure 4.2. A chart of selected unrealistic features for each V-valley animation, similar to that for flat-valley animations in the previous section, is provided in Table 4.3. One-ball and two-ball V-valley animations with the same label contain the same deviations from realistic motion, with the exceptions of race results for all motions and the gradual speed change across the final slope for the one-ball [fsl] animation.

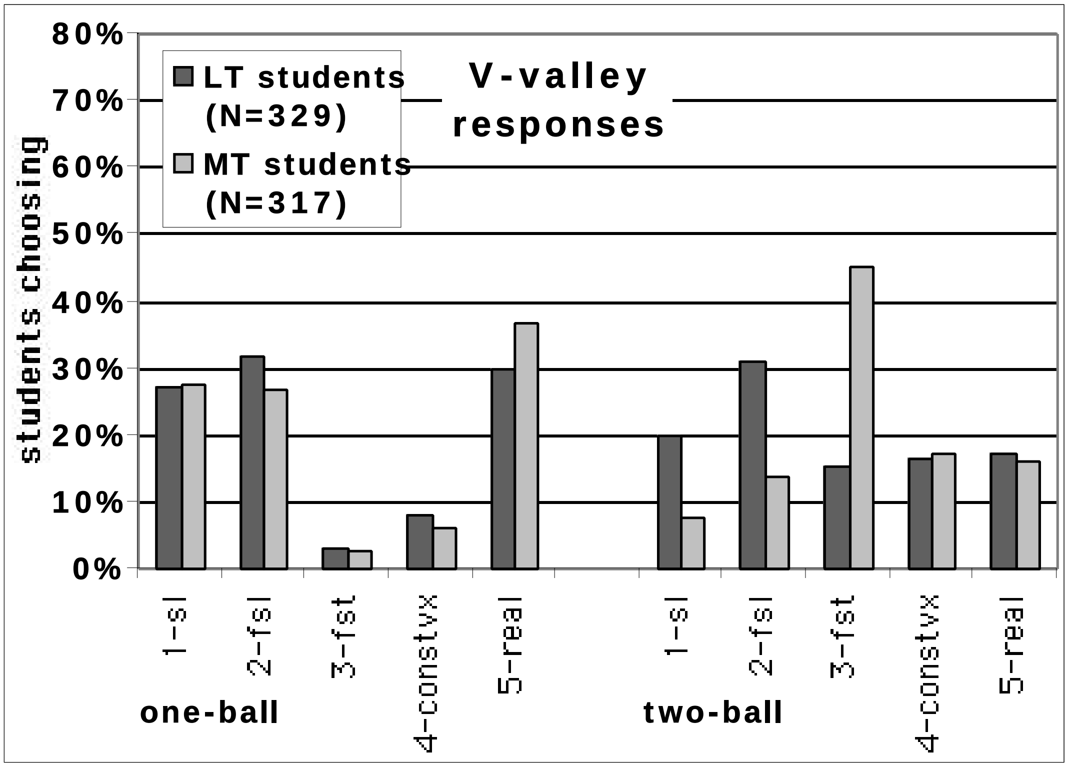

Figure 4.2 Responses to one-ball and two-ball V-valley tasks.

As shown in Figure 4.2, a small fraction of students identified the one-ball V-valley [fst] or [constvx] animations as most realistic. The majority of one-ball responses for LT and MT students were divided, approximately evenly, among the other three animations. In the two-ball V-valley task, response patterns were flatter than those in the other three tasks, with only about twice as many students choosing the most popular animation ([fst]) as the least popular ([sl]). There were differences between the two-ball response patterns for students in the LT and MT groups, however, with many more MT than LT students choosing [fst], and many more LT than MT students choosing [sl] and [fsl].

V-valley motion	1-sl	2-fsl	3-fst	4-constvx	5-real
One-ball task, percent of all students choosing	27%	29%	3%	7%	33%
Two-ball task, percent of all students choosing	14%	23%	30%	17%	17%
Deviations observable in one-ball and two-ball animations					
Speed fails to increase on second slope	X			X	
Speed fails to decrease on final slope				X	
Speed increases near end of final slope			X		
Sudden speed increase, beginning of final shelf		X			
Speed increases across final shelf		X[†]			
Slower on final shelf than on initial shelf	X	X			
Deviations observable only in two-ball animations					
Ball A wins race	X	X			
Balls A and B tie			X	X	

Table 4.3 Selected deviations from realistic motion, V-valley animations.

As shown in Table 4.3, no single feature is uniquely shared by the three most popular one-ball V-valley animations. Each of the two unpopular animations, however, contains a unique deviation from realistic motion on the final slope--speed fails to decrease as the ball rolls up the slope in the [constvx] motion, and speed increases near the end of the slope for the [fst] motion.

The most popular two-ball V-valley animation, [fst], includes the same deviations from realistic motion that apparently made the one-ball [fst] motion so unpopular, with the additional features that balls A and B cross the final shelf at the same speed and reach the end of the tracks at the same time. As was true for the flat-valley, the two V-valley "tying" animations and the two animations in which ball A won the race were identified as realistic by very different numbers of students. Differences in MT and LT response patterns for the two-ball V-valley task were also similar to those for the two-ball flat-valley task, with more MT students choosing tying animations and more LT students choosing animations in which ball A won.

4.2.3 Two-ball tying responses

As reported in sections 4.2.1 and 4.2.2, the fraction of students who chose tying motions in each task was lower for the LT group than for the MT group. As shown in Figure 4.3, there were also substantial differences in tying choice frequencies within the groups; students from more mathematically rigorous physics courses were more likely to choose a tying motion, especially for the two-ball V-valley task. The LT group consists of the first three student subgroups in Figure 4.3 (Psychology interviews, Psychology lecture, and Health Science algebra-based physics lecture). The MT group consists of the final four student subgroups in the figure (Engineering A, Engineering B and Majors calculus-based physics lectures, and Honors Engineering interviews).

---

† In the two-ball V-valley [fsl] animation, ball B has constant speed after the beginning of the final shelf.

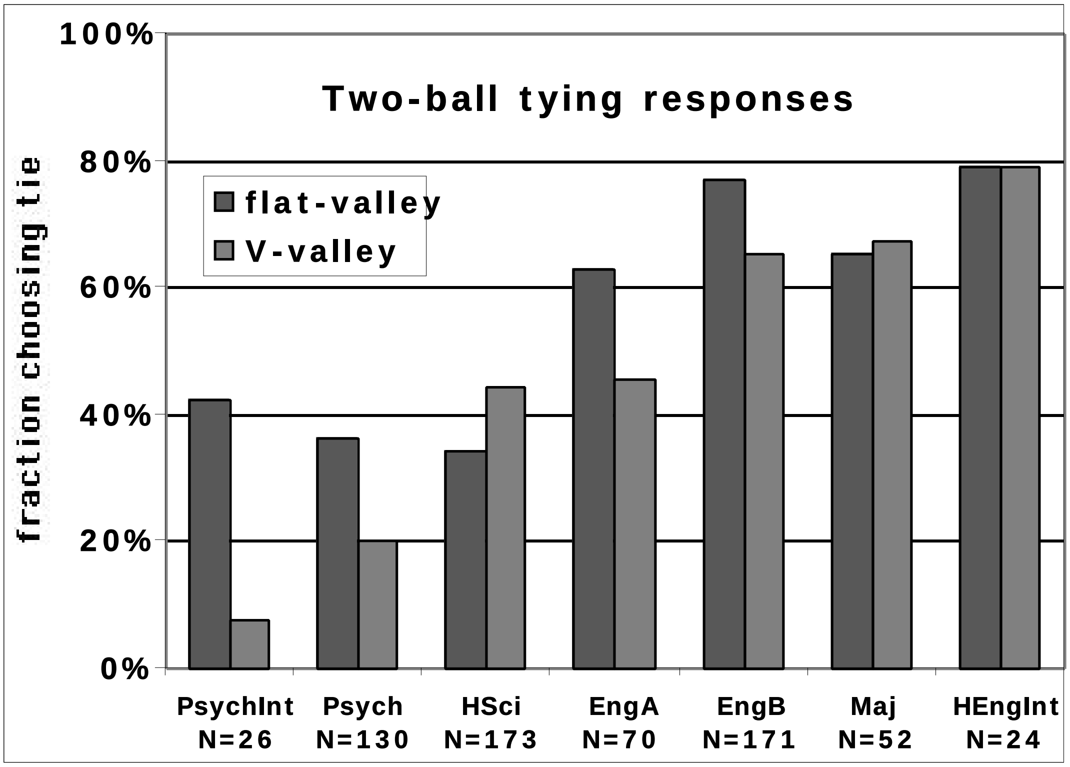

Figure 4.3 Fraction from each sub-group choosing a tying motion ([fst] or [constvx]) for each two-ball task.

The [fst] motion was relatively popular in the one-ball flat-valley task but very unpopular in the one-ball V-valley task, and the [constvx] motion was very unpopular in each one-ball task. The popularity of tying motions in the two-ball V-valley task is thus potentially more puzzling than the similar phenomenon for the two-ball flat-valley task.

4.2.4 Issues to be addressed

The structure found in the response patterns suggests that different students may have found similar ways to discriminate among the different animations. However, most students did not identify the [real] animations as depicting realistic motion. The goal of the analysis presented in the next three chapters is to understand the decision-making processes of interviewed students in terms of the coordination class construct. Among the general issues about students' coordination to be addressed are the following:

- How did students "rule in" or "rule out" animations as realistic or unrealistic? In particular, how did so many students rule out the [real] animations in favor of other animations which included deviations from realistic motion?
- To what extent does similar judgment in a task correlate with similar coordination in the task? In other words, if two students choose the same animation, do they necessarily use the same causal net elements and readout strategies, or are there distinct sets of coordination elements and processes that can lead to identical judgments?
- Can a coordination systems approach make plausible the variety of student responses?

Several comparisons of response patterns revealed differences. Between the one-ball and two-ball flat-valley tasks, the fraction of students choosing the two most popular animations ([fsl] and [fst]) was essentially reversed. The [fst] animation was chosen by a very low fraction of students in the one-ball V-valley task, but [fst] was the most popular two-ball V-valley animation. In the one-ball tasks, response patterns for the LT group were similar to those for the MT group, but this was not the case in the two-ball tasks. Students taking more mathematically-oriented physics courses were more likely to choose tying motions in the two-ball tasks, and this difference was more pronounced for the V-valley animations. Two-ball animations with the same race outcome were chosen by different fractions of students. These comparisons raise several issues, which will be addressed in the following chapters. Among these are the following:

- Did LT and MT students use similar decision-making processes in the one-ball tasks?
- How did the addition of a second ball change students' decision-making processes? Was the change more pronounced for MT students than for LT students? How can choosing animations with different features for the one-ball and two-ball tasks be understood in terms of integration and invariance?
- Did students judge two-ball animations based on the race outcome? Can exposure to school physics be used to explain an increased propensity to identify tying motions as realistic? Were some processes in students' two-ball decisions similar to processes in their one-ball decisions?
- Can a coordination systems approach make plausible the similar one-ball response patterns for MT and LT groups, while simultaneously making plausible the groups' different two-ball response patterns?