

Materials

The materials needed to play the game are game boards (24" × 36" poster board), which are lined as shown in **figures 1a** and **1b**. Five quarters are needed for each board. One blank poster board should be placed at the end of the lined board, and the player pushes the quarter across the blank board. The uniform spacing shown in **figure 1** is crucial for the analysis and interpretation of results because it determines the probability of hitting a line. For this activity, the spacing is set at two times the diameter of a quarter. The distance between lines can be increased to decrease the chance of hitting a line. The effect of the line spacing will be discussed in more detail later in this article.

Graph paper (8.5" × 11") for each student is needed for plotting individual results. You might want to use larger graphs for displaying pooled class results.

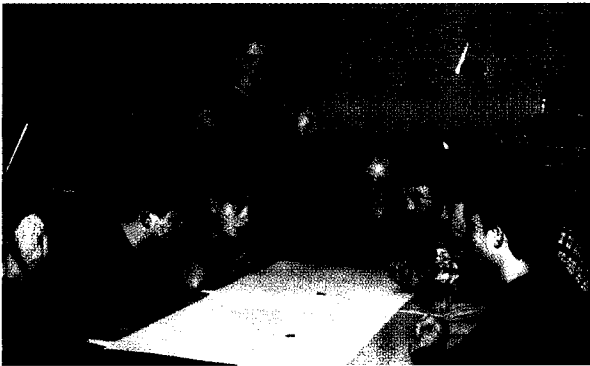


Fig. 1a The game board is shown in use.

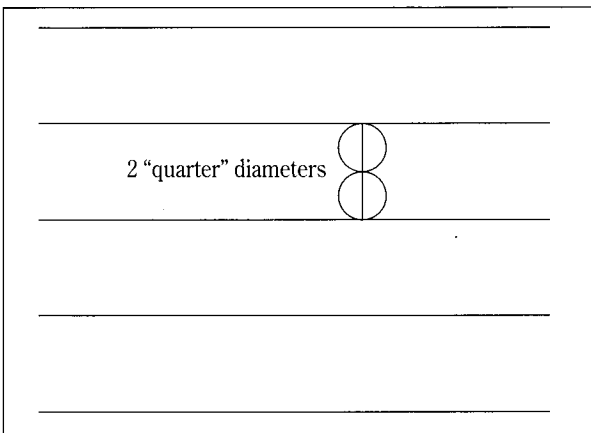


Fig. 1b Lines on the push-penny board

Scoring

THE DATA SHEET IN **FIGURE 2A** SHOWS A player's sequence of outcomes for twenty pushes. A hit is indicated by an "H"; a miss, by an "M." The score after each push is shown in the fourth column.

We shall consider two different rules, based on sums of hits and misses, for picking a winner. A third rule is based on consecutive hits. These three rules are discussed concurrently in this article but may be done separately or jointly as classroom activities.

Rule 1

The player with the largest *final score* wins. For the outcomes in **figure 2a**, the final score is +4:

$$\begin{aligned} \text{Final score} &= \# \text{ hits} - \# \text{ misses} \\ &= 12 - 8 \\ &= +4 \end{aligned}$$

The final score is 0 for the outcomes in **figure 2b**:

$$\begin{aligned} \text{Final score} &= \# \text{ hits} - \# \text{ misses} \\ &= 10 - 10 \\ &= 0 \end{aligned}$$

The player in **figure 2c** obtained a final score of -6:

$$\begin{aligned} \text{Final score} &= \# \text{ hits} - \# \text{ misses} \\ &= 7 - 13 \\ &= -6 \end{aligned}$$

The player with the largest final score is the player with the largest number of hits.

Rule 2

At the end of twenty pushes, determine the *maximum score* that was attained at any time throughout the game. The player with the largest maximum score wins.

For the outcomes in **figure 2a**, the final score is +4. The maximum score, however, is +5, which occurred after push 19. For the outcomes in **figure 2b**, the maximum score is +3, which occurred after push 5. The player in **figure 2c** obtained a maximum score of -1, which occurred after pushes 1 and 3.

Rule 3

At the end of the prescribed number of pushes, each player determines the *maximum run length* that was attained. A *run* is a string of consecutive pushes that results in hits. The length of a run is the number of pushes in the run. The player with the largest maximum run length wins.

The sequence of outcomes in **figure 2a** is as follows:

M H H M H H M H H M M H M H H H M H H M

This sequence has six runs of lengths 2, 2, 2, 1, 3, 2. The maximum run length is 3.

Examine the sequence of outcomes in **figure 2b**, and note that the maximum run length is 4. The sequence of outcomes in **figure 2c** has a maximum run length of 2.

Questions

THE ACTIVITY IS DESIGNED TO CONSIDER A SET of questions specific to each rule:

Rule 1

For one player:

- What do you expect your number of hits will be?
- What do you expect your percent of hits will be?
- What do you expect your final score will be?

For all players in the class:

- What do you expect the largest number of hits will be?
- What do you expect the largest final score will be?
- Which final scores will occur most often in the class?
- What do you expect the percent of hits will be for all the pushes made by the entire class?

Rule 2

For one player:

- What do you expect your maximum score will be?

For all players in the class:

- What do you expect the largest maximum score will be?
- Which maximum scores will occur most often in the class?

Fig. 2
Data sheets for three iterations of the game

Data Sheet				
Name	Game # _____			
PUSH	OUTCOME	VALUE	SCORE	RUN (HITS) LENGTH
1.	M	-1	-1	
2.	H	+1	0	
3.	H	+1	+1	2
4.	M	-1	0	
5.	H	+1	+1	
6.	H	+1	+2	2
7.	M	-1	+1	
8.	H	+1	+2	
9.	H	+1	+3	2
10.	M	-1	+2	
11.	M	-1	+1	
12.	H	+1	+2	1
13.	M	-1	+1	
14.	H	+1	+2	
15.	H	+1	+3	
16.	H	+1	+4	3
17.	M	-1	+3	
18.	H	+1	+4	
19.	H	+1	+5	2
20.	M	-1	+4	
Final score		+4		
Maximum score		+5		
# Hits		12		
% Hits		60		
Maximum run length		3		

(a)

Data Sheet				
Name	Game # _____			
PUSH	OUTCOME	VALUE	SCORE	RUN (HITS) LENGTH
1.	M	-1	-1	
2.	H	+1	0	
3.	H	+1	+1	
4.	H	+1	+2	
5.	H	+1	+3	4
6.	M	-1	+2	
7.	M	-1	+1	
8.	M	-1	0	
9.	H	+1	+1	1
10.	M	-1	0	
11.	H	+1	+1	
12.	H	+1	+2	2
13.	M	-1	+1	
14.	M	-1	0	
15.	H	+1	+1	1
16.	M	-1	0	
17.	H	+1	+1	1
18.	M	-1	0	
19.	M	-1	-1	
20.	H	+1	0	1
Final score		0		
Maximum score		+3		
# Hits		10		
% Hits		50		
Maximum run length		4		

(b)



Rule 3

For one player:

- What do you expect your longest run of hits will be?

For all players in the class:

- What do you expect the longest run of hits will be?
- Which run of hits will occur most often in the class?

Getting Started

THE TEACHER SHOULD INTRODUCE THIS ACTIVITY by demonstrating how to play and explaining the rule(s) for determining winners. Students can try a few pushes to see how it works. But before proceeding with the full activity, it is helpful to discuss the foregoing questions with the class. Encourage stu-

dents to explain their answers. The reasons, of course, will vary greatly, depending on the students and their experiences.

The activity is designed to answer these questions through the analysis of data. After completing the activity, the class should discuss and compare the preliminary answers with the conclusions reached from the data.

Data Collection

THE DATA SHEET FOR RECORDING RESULTS IS shown in **figure 2**. As a rule of thumb, about one hundred plays of the game are needed. For instance, if you have exactly twenty-five students, each student would play four times and complete four data sheets. Set up stations around the room, with one student managing the board, another recording results, and another playing the game. Only the "Outcome" column needs to be recorded during the game. It is very important that the Ms (for misses) and Hs (for hits) be recorded in the exact sequence that they occur.

Data Sheet

Name _____		Game # _____		
PUSH	OUTCOME	VALUE	SCORE	RUN (HITS) LENGTH
1.	M	-1	-1	
2.	M	-1	-2	
3.	H	+1	-1	1
4.	M	-1	-2	
5.	M	-1	-3	
6.	H	+1	-2	1
7.	M	-1	-3	
8.	M	-1	-4	
9.	H	+1	-3	
10.	H	+1	-2	2
11.	M	-1	-3	
12.	M	-1	-4	
13.	H	+1	-3	
14.	H	+1	-2	2
15.	M	-1	-3	
16.	M	-1	-4	
17.	H	+1	-3	1
18.	M	-1	-4	
19.	M	-1	-5	
20.	M	-1	-6	

Final score -6
 Maximum score -1
 # Hits 7
 % Hits 35

Maximum run length 2

(c)

Analysis

Individual students

After the game, the player should complete the "Value," "Score," and "Run Length" columns on the data sheets. The number and percent of hits are determined and recorded, along with the final score. The maximum score and the maximum run length are recorded. Be sure the students' names appear on the data sheets and that each student numbers his or her games in the order that the games are played.

Each student should draw two graphs (see **fig. 3**) for game 1 only:

- (a) Score versus push number
- (b) Sequence of hits or misses

These graphs, one for each student, should be displayed together so that they can be compared. To facilitate comparisons, it is recommended that all graphs be drawn on the same type of graph paper with exactly the same scaling. These comparisons are illustrated in the "Interpretation" section that follows.