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ABSTRACT

The Springs Task measures the ability to conduct controlled experiments, name variables, and criticize variables which are demonstrated to the subject. It provides an operational definition of formal thought. Subjects aged ten to adult can be tested with this instrument, an apparatus-based task administered individually in a 15-minute interview. This appendix gives details for constructing the apparatus, administering the interview, and scoring. The apparatus consists of eight springs suspended from a wooden frame, six fishing weights, 10 cup hooks, and 2 wooden cylinders. The task yields both pass/fail and points earned scores on naming variables and on conducting and criticizing experiments. Test reliability, validity, and correlations with Piagetian logic are discussed in a separate journal article. (Author/CP)

Appendix to

A Measure of Scientific Reasoning: The Springs Task*

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A Measure of Scientific Reasoning: The Springs Task
(Details for Construction, Administration, and Scoring)

As described in Linn and Rice (Journal of Educational Measurement), the Springs Task measures ability to criticize and control experiments, name variables, and analyze results. This appendix gives details for construction of the apparatus, administration of the interview, and scoring.

Construction of the Apparatus

As shown in Figure 1, the apparatus consists of a wooden frame, 8 springs, 2 slinkys, 6 fishing weights, 10 cup hooks, and 2 wooden cylinders.

To construct the wooden frame four pieces of 1" x 2" strips of wood are nailed together to form a rectangle 14" high by 18" long. A piece of oak tag is tacked to the outer edge to form a backdrop for the apparatus. Eight small cup hooks are screwed into the underside of the top piece of wood to hold the springs. A 3" piece of 1" x 2" strip with two cup hooks is attached to the top left side of the frame with a hinge.

The Weights. Six flat fishing weights, two each of 2 oz., 4 oz., and 8 oz., are needed for questions 1 through 4. For question 5, two wooden cylinders 1" in diameter by 2" high are needed. Both cylinders have eye hooks screwed into the top so that they may be hung from a spring. One cylinder is painted orange. The other cylinder is drilled out in the center and a small piece of lead is inserted in the hole to make it heavier while keeping it the same size as the first cylinder. The weighted cylinder is painted blue.

The Springs. Springs can be custom made by any springmaker as described in Table 1. The top of the spring is finished with a closed loop to hang from the cup hook. The bottom has an open loop to hang weights from. For Question 5, a regular Slinky and a Junior Slinky are used. The slinkys are cut so they are 1½" hanging length.

Interview Procedure

The questions to be asked are given in Figure 2. A detailed description of the interview procedure follows. In order to use the interview successfully, an interviewer will need to try the procedure with 2 to 5 pilot subjects. In general, the interviewer will read all questions on the protocol and record each response. Of course, the interviewer must not supply information. Whenever a response is unclear, the interviewer will choose appropriate probes from the list given after the question. It is important for the interviewer to be familiar with the scoring standards in order to be sure to probe responses which cannot be scored.

First, the interviewer hangs the springs on the hooks and places the weights on the wood strip below them. Then the apparatus is arranged so that the subject and interviewer can manipulate it easily. Both should face the frame, interviewer positioned so responses can be recorded with outside hand. The apparatus required for each question is given on the protocol in Figure 2 and summarized in Table 2.

Question 1. Make the subject at ease and read the statement with Question 1. Most subjects will start to hang weights on springs and observe the results. If the subject does not name some variables after a few minutes, interviewer can ask, "What things seem to make a difference?" Record any ideas subject has. If subject mentions size of spring it is necessary to probe to see if length or diameter is meant (e.g., say, "Show me a small spring and a large spring"). Subjects usually phrase variables in the form "how thick it is, how long it is," etc., or "if it is thick, if it is strong."

Question 2A. Most subjects will include weight in their list of variables. In any case, the experiment they do, not how they answer the questions is most important. After reading the first part of 2A, circle Yes or No. Then ask, "Do an experiment to find out whether weight makes a difference." Circle the springs and weights the subject uses. For example, if an 8 oz. weight is placed on spring 3 and a 4 oz. weight on spring 2, the experiment is recorded as shown below.

SPR	1 2 (3) 4 5 6 7 8	WTS	2 4 (8)
	1 (2) 3 4 5 6 7 8		2 (4) 8

After recording the experiment ask the subject, "Why did you do the experiment that way?" If subject does not reply or says, "To show that weight makes a difference," use Probe 1.

The only controlled experiment possible for question 2A uses one spring and two different weights. Many subjects search for two springs that appear to be the same and may verbalize this as they pull on the springs trying to find two of comparable springiness. If the subject does this and states that no two are alike, interviewer may recognize the dilemma and ask, "If that is so, what can you do about it?" This helps some subjects to realize that they will have to put two different weights on the same spring, but it does not give them any information or indicate that the interviewer agrees with the finding.

If the subject does a controlled experiment but can't seem to give a reason for it, use Probe 1 to direct his/her attention to the choice of springs and weights.

If the subject does an uncontrolled experiment, use Probe 2 or 3. If the subject says "Yes" to Probe 2 or "Weights make a difference" to 3, then the interviewer shoud go on to question 2B. If the subject says "No" to Probe 2 or "Springs and weights matter" to Probe 3, then ask Probe 4. Record any new experiment and ask Probe 5, "Is it better to use one spring twice than two springs once?" After subject says "Yes" or "No" ask "Why?"

Question 2B. Circle subject's response of "Yes" or "No," then ask "Why?" Many subjects need to do the experiment before they can answer the question. While this is unnecessary and often indicates the subject is focusing on the results of the experiment rather than the procedure, subject may be allowed to carry out the experiment before answering the question. An alternate procedure is for the interviewer to hang the weights on the spring and allow subject to observe the results.

Question 3A. This question may be handled in the same way as 2A. A controlled experiment uses the same weight and either springs 1 and 2 or 7 and 8. If

subject does an uncontrolled experiment and answers "No" to probes such as "Does it matter that one spring is long and one is short?" go on to Question 3B. However, if subject replies "Yes" to two such probes, ask, "Is there another way to do the experiment? How would you do it?" Then allow subject to do a new experiment and ask, "Is this a better way to test for fatness? Why?"

Question 3B. It is handled as 2B.

Question 4A. This question may be handled in the same way as 2A. A controlled experiment uses the same weight and either springs 2 and 3 or 5 and 7. If subject does an uncontrolled experiment and answers "No" to probes such as "Does it matter that one spring is long and one is short?", go on to Question 3B. However, if subject replies "Yes" to such probes, ask "Is there a better way to do the experiment? How would you do it?" Then allow subject to do a new experiment and ask "Why is that better?"

Question 4B. It is handled as 2B.

Question 5. Remove short fat springs and tell subject, "Remember that in this question you are an observer and will watch what happens in the experiment." Then read question 5 as you hang up the slinkys. Hang the blue weight on the small slinky and the orange weight on the large slinky as you say, "Erin decided to hang these two wooden weights from the springs. Watch what happened." Read A. If subject reaches for the wooden weights before answering A ask, "Why do you want to touch them?" Many subjects then reply, "To see if they are the same." Interviewer can then ask, "Would it matter if they weren't?" and record the answer. The rest of question 5 is straightforward. Continue to ask questions until subject recognizes that the weights may not be the same. It is important to record when the subject realized that the weights could be unequal.

Scoring Responses

Question 1. The score is equal to the number of different variables named.

Question 2A.

4 points: Subject does a controlled experiment and justifies by saying, "One spring might be stronger," "You have to use the same spring to show weight makes a difference," "To make it fair," "No two springs are the same," "Everything has to be equal except the weight."

3 points: Subject does a controlled experiment and gives same answers as above only after a probe such as "Is it OK to use different springs?" or "Why only one spring?" Subject does a controlled experiment and says, "I used different weights and the same spring."

2 points: Subject does a controlled experiment but repeats questions or focuses on weights in justification: "To see which weight stretches it most," "I used biggest and smallest weight," "It was a stretchy spring."

2 points: Subject does an uncontrolled experiment (uses two springs) but says the springs were similar, then does a controlled experiment in response to Probe 4 and justifies it by recognizing that no two springs are the same in response to Probe 5.

1 point: Subject uses 2 springs but justifies the experiment by saying, "The springs have the same springiness" or "The springs are almost the same." Subject does a controlled experiment in response to Probe 4 but can't answer Probe 5, or says 2 springs are just as good.

0 points: Wrong. Subject uses one trial and says, "I don't know," or doesn't do an experiment.

Question 2B.

3 points: "Yes, because he used the same spring and different weights," "Yes, no two springs are the same."

2 points: "Yes, same spring."

1 point: "Yes, used different weights."

0 points: "No, weights are close in size."

Question 3A. For this question very few subjects choose springs 7 and 8, a few more choose 1 and 2, but quite a few choose 4 and 7 which are controlled for everything except length.

4 points: Subject uses controlled experimeht (uses same weight on springs 7 and 8) and justifies by saying, "Everything is equal except for the fatness," "Same weights and same kind of spring," "Springs have to be the same material to make it fair."

3 points: Subject chooses similar springs (e.g., 1 and 2, 4 and 7) and same weights and justifies by saying, "Same weights and springs looked like same material," "The springs are the same length (used 1 and 2) and the weights are the same." Subject does controlled experiment but mentions only sameness of weights or (not and) springs.

2 points: Subject chooses similar springs and same weights but mentions only weights or similarity of springs: "The thickness of the wire is the same" (for 1 and 2), "The weights are the same," or "One spring is fat and one is thin." Subject does an uncontrolled experiment but in response to Probe 4 does a controlled experiment and justifies it properly in answer to Probe 5.

1 point: Subject chooses a less suitable pair of springs (e.g., 2 and 6), and may show an awareness of the need to control variables by saying, "Weights are the same," "Springs are of the same material." Subject does a controlled experiment in response to Probe 4, but says "No" to Probe 5.

0 points: Wrong. One trial, no response.

Question 3B.

2 points: "No, one spring is longer."

1 point: "Yes, same weights" or "Yes, springs are brass."

0 points: "Yes," "Looks good," etc.

Question 4A.

4 points: Subject uses controlled experiment (uses same weight on springs 2 and 3 or 5 and 7) and justifies by saying, "Everything is equal except for the material." "Same weights and same kind of spring." "Springs have to be the same to make it fair."

3 points: As for 4 points but gives justification after probe.

2 points: Subject chooses similar springs and same weights but mentions only weights or similarity of springs. "The weights are the same," or "One spring is brass and one is steel." Subject does an uncontrolled experiment but in response to Probe 2 does a controlled experiment and justifies it properly in response to Probe 3.

1 point: Subject chooses a dissimilar pair of springs and may show an awareness of the need to control variables by saying, "Weights are the same." Subject does a controlled experiment in response to Probe 4, but says "No" to Probe 5.

0 points: Wrong. One trial, no response.

Question 4B.

3 points: "No, one spring is longer and has a thicker coil."

2 points: "No one is longer," or "No, one has a thicker coil."

1 point: "Yes, same weights" or Yes, different material."

0 points: "Yes", "Looks good", etc.

Question 5.

4 points: "No because you don't know if the weights are the same." Subject reaches to touch weights, interviewer asks, "Why do you want to touch them?" Subject: "To see if they're the same." Interviewer: "Does it matter?" Subject: "Yes, if they're not the same you don't know."

3 points: Subject says "Yes" to A and now says, "No, maybe weights are not the same," or "No, maybe one weight is heavier."

2 points: Subject says "Yes" to A and B and now says "Yes, do these wooden things weigh the same?" or "Yes, are these the same size?"

1 point: "No, the blue is probably heavier."

0 points: Subject's responses to A, B, C, D are "Yes, Yes, No, Yes."

Composite Scores. The above scores can be combined to get a Variables, Controlling, Criticizing, and Analysis score. The Variables score is the score on question 1. The Controlling score is the sum of the scores on questions 2A, 3A, and 4A. An alternative is to count the number of scores of 3 or above on these items. The Criticizing score is the sum of scores on 2B, 3B, 4B. An alternative form of this score is to count the number of scores of 2 or above on these items. The Analysis score is the score on question 5.

TABLE I

SPECIFICATIONS OF SPRINGS

SPRING NUMBER	MATERIAL	LENGTH (INCHES)	DIAMETER OF COIL (INCHES)	THICKNESS OF WIRE (INCHES)
1	steel	2	.25	.018
2	steel	2	.335	.018
3	brass	2	.335	.018
4	brass	2	.335	.025
5	steel	1.5	.25	.025
6	steel	1.5	.25	.018
7	brass	1.5	.25	.025
8	brass	1.5	.335	.025

TABLE 2

DESCRIPTION OF SPRINGS APPARATUS

SPRING NUMBER	METAL	THICKNESS OF WIRE	FATNESS OF SPRING	LENGTH
		Questions 1, 2, 3, 4		
1	steel	thin	thin	long
2	steel	thin	fat	long
3	brass	thin	fat	long
4	brass	thick	fat	long
5	steel	thick	thin	short
6	steel	thin	thin	short
7	brass	thick	thin	short
8	brass	thick	fat	short
(weights: 6 metal flat fish weights)				
		Question 5		
Regular slinky	steel	thick	fat	1½ inches hanging
Junior slinky	steel	thick	thin	1½ inches hanging
(weights: metal cylinders that look the same, but weigh differently)				

Figure 1: Springs Apparatus

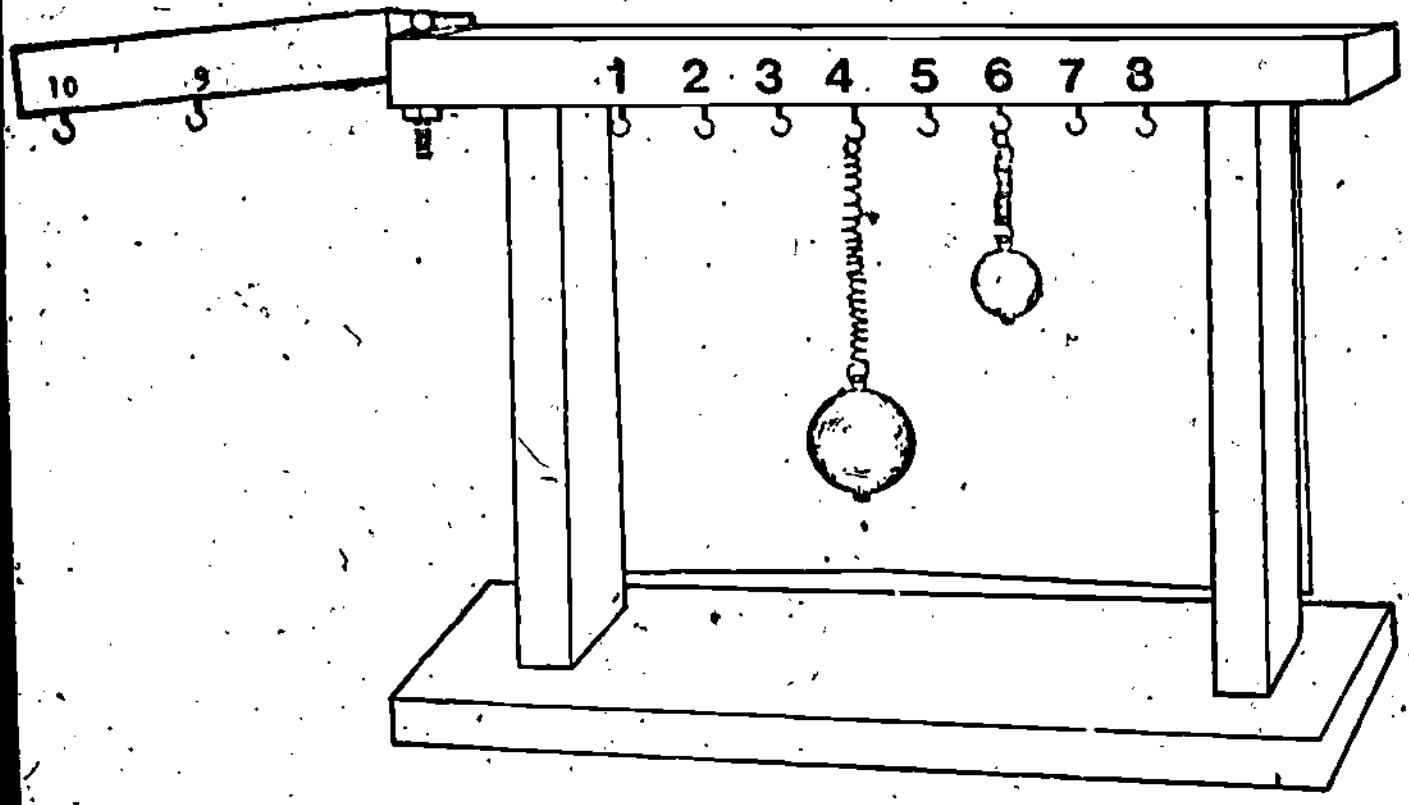
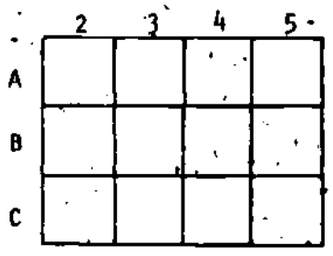


FIGURE 2

SPRINGS QUESTIONS AND RESPONSE SHEET

Var ☐



SPRINGS

Materials:

stand
8 springs
2 slinkys
6 flat fishing weights
2 wooden weights

Name_____ Grade_____

Sex: M F Age_____ Experimenter_____

School_____ Date_____

IMPORTANT NOTE: If subject's response is unclear or incomplete use one or more probes.

1. (Hang 8 springs on the apparatus. Set fishing weights out in front of subject.) Here I have some springs. I can hang these weights from them. Experiment with them and tell me what might make a difference in how far they expand.

_____ _____ _____

_____ _____ _____

_____ _____ _____

2A. Now, do you think the amount of weight makes a difference in how far the spring will expand? Yes No

Do an experiment to find out whether weight makes a difference:

SP: 1 2 3 4 5 6 7 8 WT: 2 4 8

SP: 1 2 3 4 5 6 7 8 WT: 2 4 8

Why did you do the experiment this way?

Probes:

1. Why did you use this spring and these weights?
2. Is it O.K. to use different springs to see if weight makes a difference?
3. What does your experiment show?
4. Could you find out about weight by using one spring twice? Yes No
   How would you do it?

5. Is it better to use 1 spring twice than to use 2 springs once? Yes No
Why?

2B. Someone else wanted to prove that weight makes a difference. He tried spring #6, once with wt. 2 and once with wt. 4. Is this a good way to prove weight makes a difference? Yes No Why?

3A. Do you think the fatness of the spring makes a difference in how far it expands? Yes No

Do an experiment to find out whether fatness makes a difference:

	1	2	3	4	5	6	7	8		2	4	8
SP:									WT:			
	1	2	3	4	5	6	7	8		2	4	8

Probes:

1. Why did you use these springs and these weights?

2. Does it matter that this one is long and that one is short? (silver/bronze; thick/thin; etc.)?

3. Would lighter/heavier weights be just as good?

4. Is there another way to do the experiment? How would you do it?

5. Is this a better way to show if fatness makes a difference. Yes No Why?

3B. Someone else wanted to find out whether fatness makes a difference in how far down the spring stretches. He tried springs 4 and 7 (Wt. #4). Is this a good experiment? Yes No Why?

4A. Now do you think the material the spring is made of makes a difference in how far the spring will expand? Yes No

Do an experiment to find out whether material makes a difference:

	1	2	3	4	5	6	7	8		2	4	8
SP:									WT:			
	1	2	3	4	5	6	7	8		2	4	8

Probes:

1. Why did you use these springs and these weights?

2. Does it matter that this one is long and that one is short? (Circle one) (thick/thin; fat/skinny; heavy/light)? Yes No Why?

3. Is there a better way to do the experiment? Yes No How would you do it?

4. Why is that better?

4B. Someone else wanted to find out whether material makes a difference. He tried springs 4 and 5 (Wt. #2). Is this a good experiment? Yes No Why?

5. (Hang two slinkys on stand, use wooden weights.) Suppose there was another contest and for this contest Erin was choosing between these two springs. Before the contest, Erin decided to hang these two wooden weights from the springs (blue wt. on small spring). Watch what happened.

5A. From this experiment do you know which spring you would choose for the contest? Yes No Big Small Why?

5B. Do you have enough information to decide which spring to choose? Yes No Why?

5C. Would you have any questions to ask Erin? Yes No What?

5D. Do you think these wooden things weigh the same? Yes No