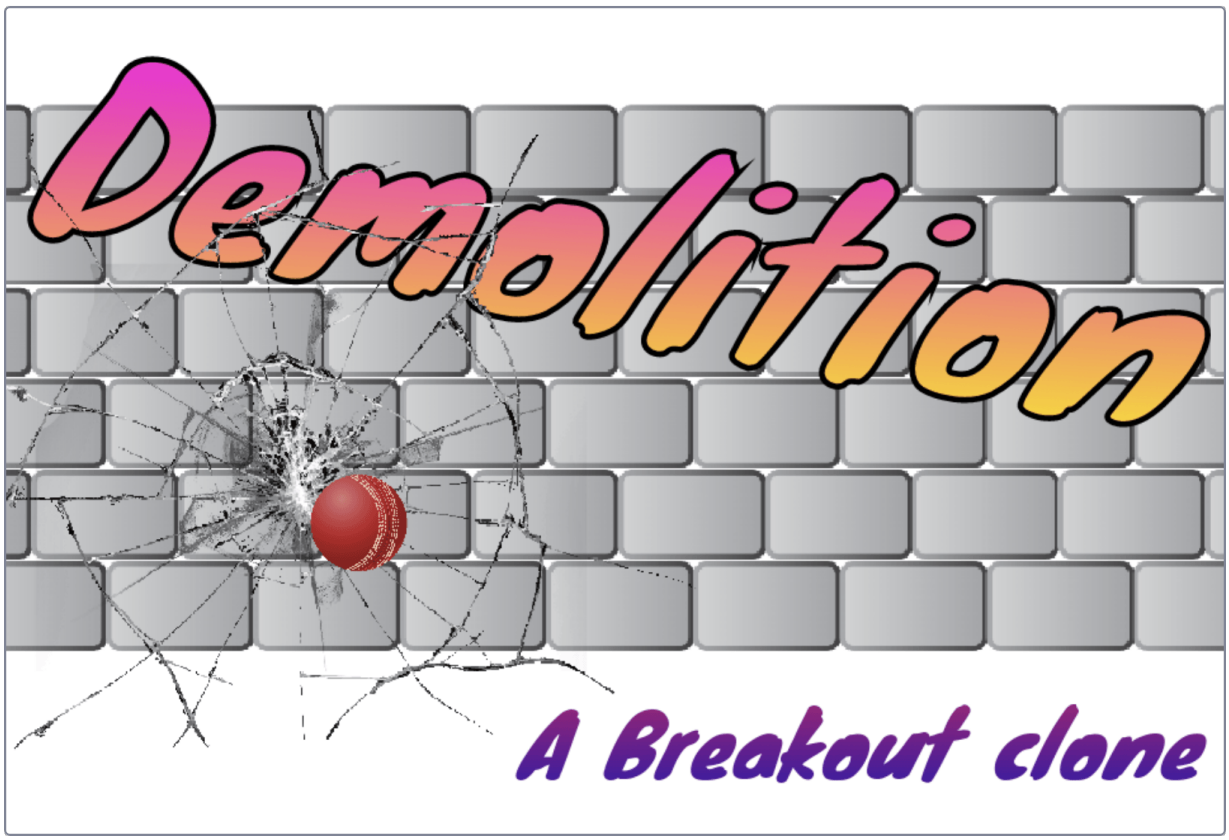
Demolition:
A Tutorial On Creating A Clone Of The 1970s Arcade Game *'Breakout'* In Scratch



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1. Introduction

This project is an intermediate to advanced Scratch [https://scratch.mit.edu] (version 3) programming tutorial which will walk you through creating a clone of the classic computer game *Breakout* [https://en.wikipedia.org/wiki/Breakout_(video_game)] from the 1970s.

In the game, the player tries to knock a ball against a wall of bricks in order to demolish the wall. As the ball bounces off the wall, the player tries to knock the ball back towards the wall using a bat. The player wins the game by completely destroying the wall. If the player fails to knock the ball back towards the wall with the bat, the ball drops off the bottom of the screen and the ball is lost.

In this project we will cover various coding concepts which are marked with the "ribbon tied to a finger" icon shown to the left. These include:

- variables (see page 73): places to store information which can change while your code is running
- loops (see page 72): telling the computer to do the same thing more than once
- blocks [https://en.scratch-wiki.info/wiki/Blocks] : chunks of code that can be reused
- parameters (see page 73): information passed to a block that tells the block more precisely how to behave
- events (see page 72): things which happen in one part of your code which another part needs to know about (often done in Scratch by broadcasting and receiving messages)
- cloning [https://en.scratch-wiki.info/wiki/Cloning] a sprite: creating (and destroying) copies of the same sprite

This is not a tutorial meant for complete beginners: if you are a Scratch beginner, I suggest you look at the Code Club Scratch modules [https://projects.raspberrypi.org/en/codeclub] and the CoderDojo Scratch projects [https://projects.raspberrypi.org/en/coderdojo/35] . If you are following this tutorial, I am assuming that you have at least a basic level of Scratch knowledge.

I have provided code for all the steps in this project (and the optional challenges), so don't worry if you get a bit stuck. I have also tried to add useful comments to my code to explain what it's doing.

My solution is probably not the only possible solution as there is usually more than one way to do something. It may not necessarily be the best solution, so if you have a better idea, feel free to contact me [mailto:scratch@pocketfluff.net] .

1.1. Design Principles

In writing our code I am going to try to use good programming practice and I encourage you to do the same. Specifically, I mean:

- write small blocks of code:
- test the small blocks as we write them
- reuse blocks where possible
- organise things logically: for example, give variables which relate to bricks names beginning with `brick.` e.g. `brick.width`, `brick.height`

Following these guidelines will help make our code easier to read, test and extend later on.

2. Game Layout

In the game, the screen (which Scratch calls the Stage [https://en.scratch-wiki.info/wiki/Stage]) is laid out as follows:

- a wall of bricks at the top
- a strip of water across the bottom; if the ball falls into the water, it is lost
- a bat which the player moves from left to right above the water
- a ball which bounces around the stage

When the player launches the ball it starts travelling up the screen (usually diagonally). When the ball hits a brick, the brick breaks and disappears, and the ball bounces back off it, usually back down the screen towards the bat. When the ball hits the bat, it bounces off it and travels back up the screen towards the wall. The aim of the game is to knock out all the bricks in the wall without losing the ball into the water.

You can probably guess that the bat and ball will be Scratch sprites [https://en.scratch-wiki.info/wiki/Sprite] . I have chosen to make the water strip a sprite too rather than making it part of the backdrop, because that makes it easier to move around, easy to detect when the ball falls into it, and it can be animated by changing its costume. It can also be removed simply by hiding the sprite.

We will also need brick sprites to build our wall. Now we could design one brick sprite and then duplicate it several times, moving each duplicate into the right position in the wall. But there are a few reasons why we don't want to do that:

- It's slow: even building a wall of 10 bricks like this would be tedious; imagine if want 100 bricks, or 1000!
- Each brick would be a separate sprite which would make it very hard to change later on:
  - if we decide to redesign the costume, we'd have to change it for every single copy
  - if we add code to a brick sprite, we'd need to copy that code to every sprite

What we really want is for every copy of the brick sprite to behave in the same way, and that means we want each copy to share the same costumes, sounds and code. Fortunately, Scratch gives us a way to do exactly that: we can *clone* [https://en.scratch-wiki.info/wiki/Cloning] (in other words: make a copy of) a sprite many times over. All we need is one brick sprite to act as the template.

We also need a logical place to put the code that builds the wall. It doesn't belong in the brick sprite because the code controls the behaviour of the wall of bricks as a whole, not of each individual brick. We could put the wall code into the stage, but I have chosen to put it into a `wall` sprite (which will have no costume and be invisible). This means the stage can stay clean by containing only code that relates to the game as a whole. It also allows me to have variables which can only be seen by the wall's code (Scratch calls these *local* or *private* variables [https://en.scratch-wiki.info/wiki/Variable#Local_Variables]).

So to sum up, these are the sprites we will need in our game:

- `bat`
- `ball`
- `water`
- `brick`
- `wall`

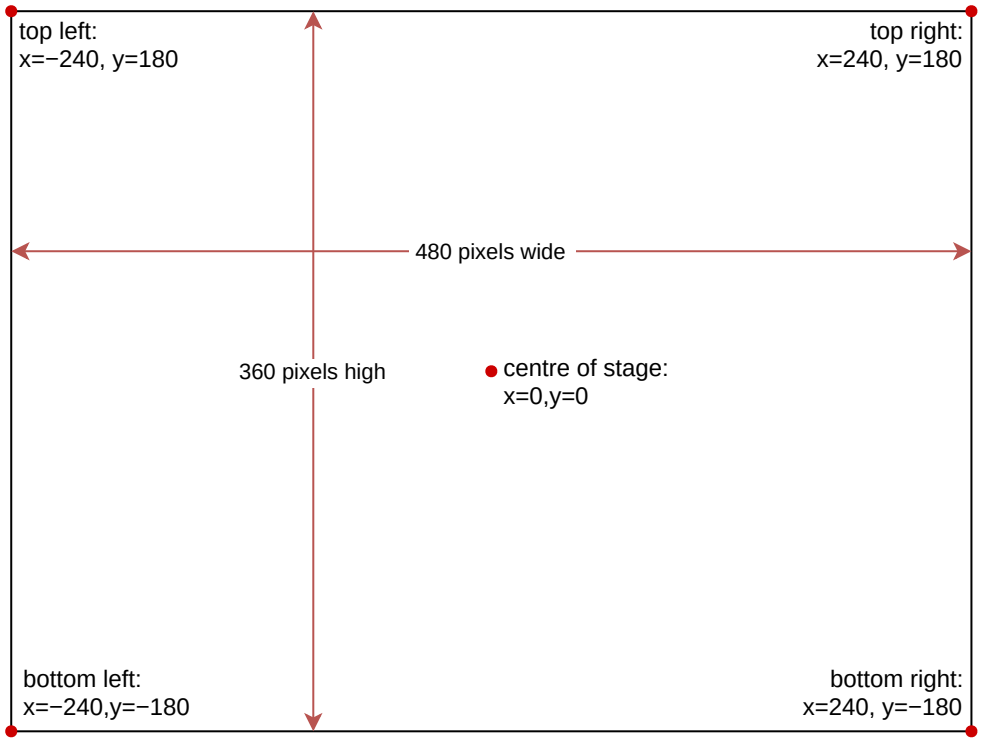
2.1. About The Stage: Dimensions and *x* and *y* Positions

The stage in Scratch is a fixed size: 480 pixels (see page 73) wide by 240 pixels high.

In Scratch, you describe a point on the stage by its *x* and *y* coordinates. The *x* coordinate specifies how far across the stage from left to right the point is. *x* coordinates run from −240 (the left edge of the stage) to +240 (the right edge); an *x* value of 0 means the horizontal centre of the stage.

Similarly, the *y* coordinate tell us how far up or down the stage a point is. *y* coordinates run from −180 (the bottom edge of the stage) to +180 (the top edge); a *y* value of 0 means the vertical centre of the stage.

Take a look at the diagram of the stage below:



Dimensions Of The Scratch Stage

We can see that the point with position *x=0* and *y=0* is at the centre of the stage. The *x* and *y* positions of each corner of the stage are also shown.

This diagram will be useful later when we want to work out where on the stage to place our bricks when we want to build a wall.

2.2. Events: Things that happen during the game

An *event* is simply something that happens which requires our code to take action. It can be caused by the user, for example by pressing a key or clicking the mouse, or by the computer when some condition arises while code is running.

When coding in Scratch, it is often helpful to think about the events that the program will need to handle. To put it another way, we can ask ourselves:

> "What might happen during the game, and what should the code do in response?"

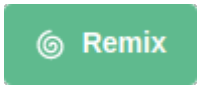
I asked myself that question and my answers are summarised in the table below.

Event	Action required
start of the game: setup	• set the stage to the correct backdrop • build the wall of bricks • set the ball's starting position & direction
the player launches the ball	• start the ball moving around the stage
the player moves the mouse left or right	• move the bat left or right accordingly
the ball hits the bat	• the ball bounces off the bat back up the stage
the ball hits a brick	• the brick breaks and disappears • the ball bounces off the brick
the last brick is broken	• tell the player that the game is won • end the program
the ball falls into the water	• hide the ball • tell the player that the game is lost • end the program
the player pauses the game	• the ball stops moving until the player resumes the game

Events that might occur during the game

3. The Template Project

OK, let's fire up Scratch and open the template Scratch project for this tutorial [https://scratch.mit.edu/projects/396280114/] .

Sign in to Scratch and then click 

to create your own copy of the template.

The template project contains:

3.1. The Stage

The stage contains four backdrops:

- a completely blank backdrop named `blank`
- a backdrop named `round completed` with a simple *"well done"* message that we can show to the player when he/she has completely demolished the wall
- a backdrop named `game lost` with a *"bad luck"* message that we can show to the player when the game is lost
- a backdrop named `title screen` which be shown when the project is first opened and will also be used as the title image for the project

It also contains one sound: the `Tada` sound from the Scratch library which will play when the player breaks the last brick.

3.2. The `bat` Sprite

The `bat` sprite is a copy of the `Button2` sprite from the Scratch libary. It is very simple: it has only one costume and one sound, the `Tennis Hit` sound which will play when the ball hits the bat.

3.3. The `ball` Sprite

For the `ball` sprite I have just used the `Ball` sprite from the Scratch library. It has 5 costumes, so select whichever colour costume you like best (I went for green). It also has one sound: the `Splash` sound from the Scratch library which will play when the ball falls into the water.

3.4. The `water` Sprite

For the `water` sprite I found a nice wave animation on Youtube [https://www.youtube.com/watch?v=OjlAyPSeOvg] and cropped (see page 72) it down to a suitable size. Each costume is one frame [https://en.wikipedia.org/wiki/Film_frame] of the animation so we'll need to show each costume in turn to animate the water. It has no sound, but you could add sound if you like — perhaps the `Ripples` library sound would be a good starting point.

3.5. The `brick` Sprite

The `brick` sprite is a copy of the `Button3` sprite from the Scratch library. I have given it:

- 5 costumes of different colours so we can build a multi-coloured wall. Later we could extend the game so that different colours of brick do different things (e.g. award bonus points, drop power-ups for the player to catch with the bat etc).
- one sound (a quieter version of the `Drum Bass1` library sound) which we'll play when the ball hits a brick.

The `brick` sprite is (at the size I have chosen) 40 pixels (see page 73) wide by 24 pixels high. This will be important later when we want to build a wall of bricks side-by-side.

3.6. The `wall` Sprite

The `wall` sprite is a completely empty sprite, set to invisible, which will hold our wall-building code.

4. Let's Code!

It can be overwhelming when you first start thinking about writing a program: it's often difficult to know what to do first. I have broken the game down into "tasks" that our code needs to perform, so we can write (and test) our code a little at a time.

Each section below introduces a task, a problem our code needs to solve. Each green box below describes the task and invites you to try writing the code to do perform it. I have also provided my code so you can see how I've solved each problem.

My code is hidden in case you want to try writing your own code without looking at mine: simply click or tap on "See my code" to reveal it. Similarly with hints: click or tap on "Hint" to reveal the hint.

Right, that's enough introduction — let's get coding!

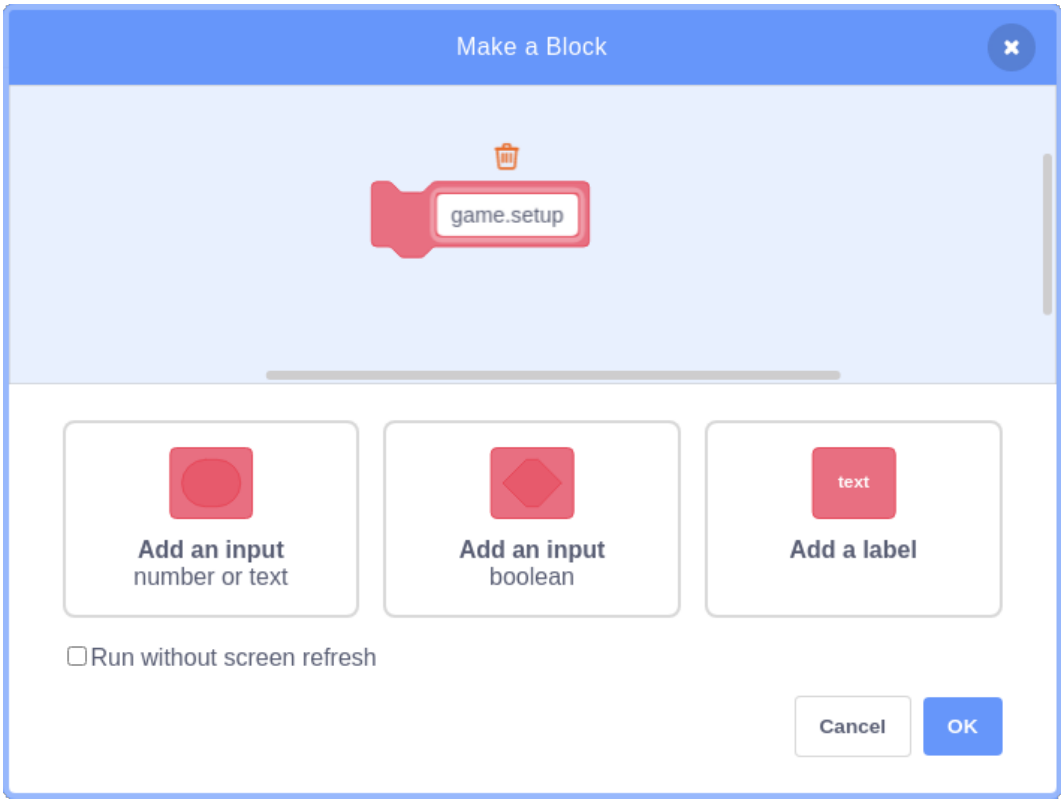
4.1. Set up the game

Most computer code needs to do some setup or initialisation when it is first run, and our game is no different. Let's create a custom block to hold our setup code. Creating a custom block allows us to keep our setup code grouped together, making our code tidy and easy to read, understand and extend later on.

Task

Create a custom block named `game.setup` in the `stage`. To do this go the 

category and click the "Make a Block" button. Type the name `game.setup` and click OK.

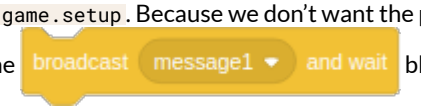


Make a block to hold the setup code

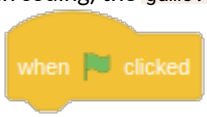
This will create a Scratch block labelled `define game.setup`; we can now add code under that block that will run whenever we use the `game.setup` block.

What does our setup code need to do? If you refer back to the section Events: Things that happen during the game (see page 6) you may remember that (among other things) it needs to set the stage to the correct backdrop. That's a simple step so let's add it to our `game.setup` block now (the other steps we can add later).

We also need to tell the other sprites to perform their setup tasks too. In Scratch, whenever we need to ask another sprite to do something we *broadcast* a *message*. Other sprites can listen out for messages and when they hear a message they're interested in, they can take some action.

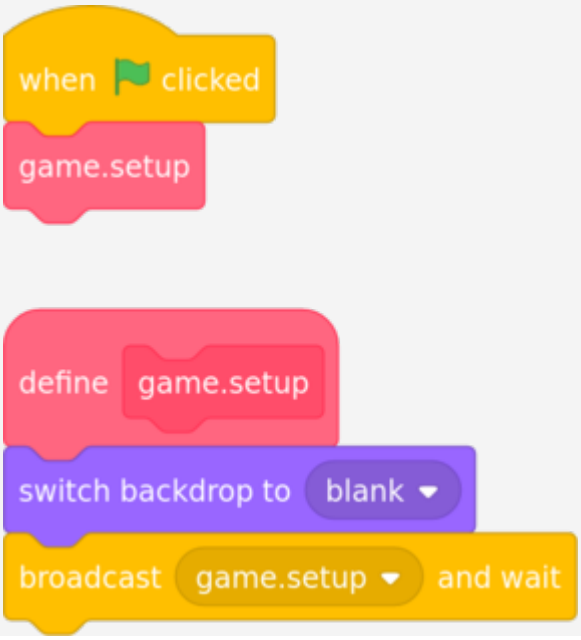
Add code to the `game.setup` block to broadcast a message called `game.setup`. Because we don't want the program to do anything until all the setup code has finished, we need to use the 

block.

Finally, we need to get Scratch to run (or *call* as we say in coding) the `game.setup` block. The usual way to start a Scratch program is to click the green flag, so let's add a 

block and get it to call the `game.setup` block.

See my code:



Having written our first piece of code, we need to test it. For now let's just check that it changes to the correct backdrop: manually set the stage to one of the other backdrops (either the winning or losing backdrop will do), and click the green flag. Does the stage change to the blank backdrop?

Once you're satisfied that your code does what it should do, move on to the next section.

4.2. Let the player control the bat

The bat is positioned near the bottom of the stage at position *y=−135*. We want the player to be able to move it left and right (but not up and down) using the mouse.

Again, we'll use an event to let the bat know when to start moving: I called the event `game.round_start` because it signifies that a round of the game (by "round" I mean a passage of gameplay that starts with the player launching a ball and ends when either the ball falls into the water or the wall is completely demolished) is about to start.

Task

Add code to the `bat` sprite to tell it to follow the mouse left and right, but not up and down. Remember to broadcast the `game.round_start` at the start of the program (add it under the 

block in the `stage`).

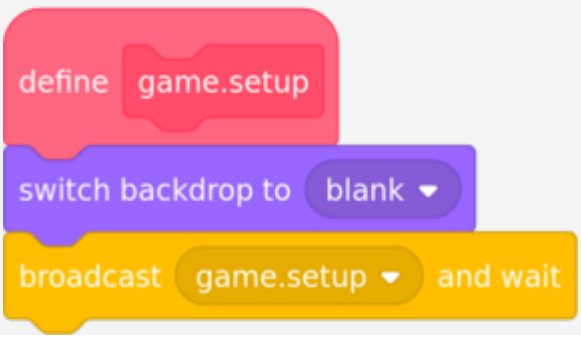
Hint:

We want the bat to follow the mouse's *x* position but stay at its own current *y* position.

See my code:

In the `bat` sprite:

In the `stage`:



Again, test your code to check that it does what you want before moving on to the next section.

4.3. Get the ball to bounce around the stage

I have given the ball a fixed starting direction of 40 (i.e. when it moves, it will travel upwards and to the right). I will discuss direction in Scratch in more detail later in the section Direction in Scratch (see page 29).

Task

Add code to the `ball` sprite to tell it to continually move around the stage, bouncing if it hits the edge. How fast you move the ball is up to you.

See my code:

To allow the game to vary the speed that the ball moves, I created a variable named `ball.speed`. I found setting it to 8 (so that the ball moves 8 steps at a time) makes the ball move at a reasonable speed. Later on we could make the speed of the ball vary, perhaps getting faster as the games goes on.

As always, test your code.

4.3.1. Challenge: Start the ball moving in a random(ish) direction

See Challenge: start the ball moving in a random(ish) direction (see page 37).

4.4. Start and stop the ball

We have already discussed the events that will cause the ball to start and stop moving (see the section *Events: Things that happen during the game* above (see page 6)). Now let's put that planning into action.

We need a way for the player to "launch" the ball at the start of the game. I decided that the player should be able to do this either by clicking the mouse (on the stage or the bat), or by pressing the space key. In response to the player's mouse click or key press we need to tell the ball to start moving.

As I mentioned earlier, whenever we need to ask another sprite to do something in Scratch we broadcast a message. Other sprites can receive messages and take action. I called the message `ball.start`.

There are several events that should cause the ball to stop moving, so we'll also need a message for that: I used `ball.stop`.

Task

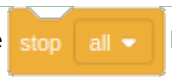
Write code to broadcast the `ball.start` message in response to the player clicking or pressing space. Then adapt the code to bounce the ball around the stage (see page 12) we wrote above to listen for this message and set the ball moving.

Once you've got that working, add code to stop the ball moving in response to the `ball.stop` message: for now, just trigger that message in response to a key press: let's use *P* for pause.

Hint:

The code which moves the ball uses a 

loop. As it stands there is no way to exit this loop and stop the ball moving.

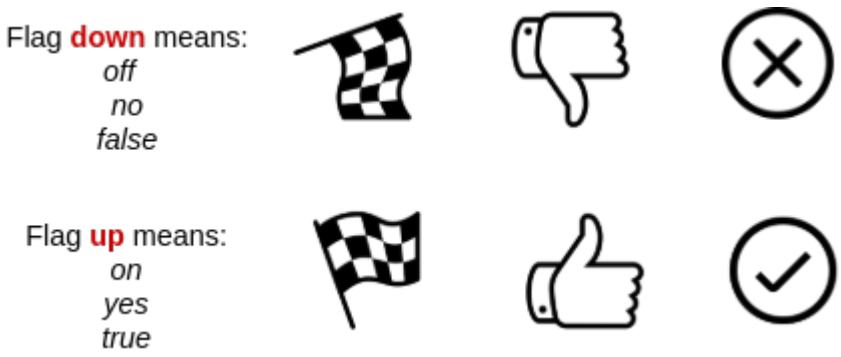
We could perhaps use the 

block but that would stop all scripts in all sprites, effectively ending the program, and we don't necessarily want to end the whole game. The player may want to simply pause the game and carry on from where they left off.

We need a "clean" way to exit the *forever* loop and stop the ball moving.

See my solution:

I decided to use a flag (see page 72) variable to tell the *forever* loop when to exit. A flag has two possible states: it is either on or off. You can think of the flag as either being *up* (or *on*, or meaning *yes*) or *down* (or *off*, or *no*). This type of variable is often known as a Boolean [https://en.wikipedia.org/wiki/Boolean_data_type] variable.



Flag variables

I named my flag variable `ball.in_motion`:

- To begin with it has a value of `0` which I use to mean *no* or *is not moving*.
- When the ball starts moving I set `ball.in_motion` to `1` (meaning *yes* or *is moving*).
- When the ball receives the `ball.stop` message, it sets the `ball.in_motion` flag back to `0`.

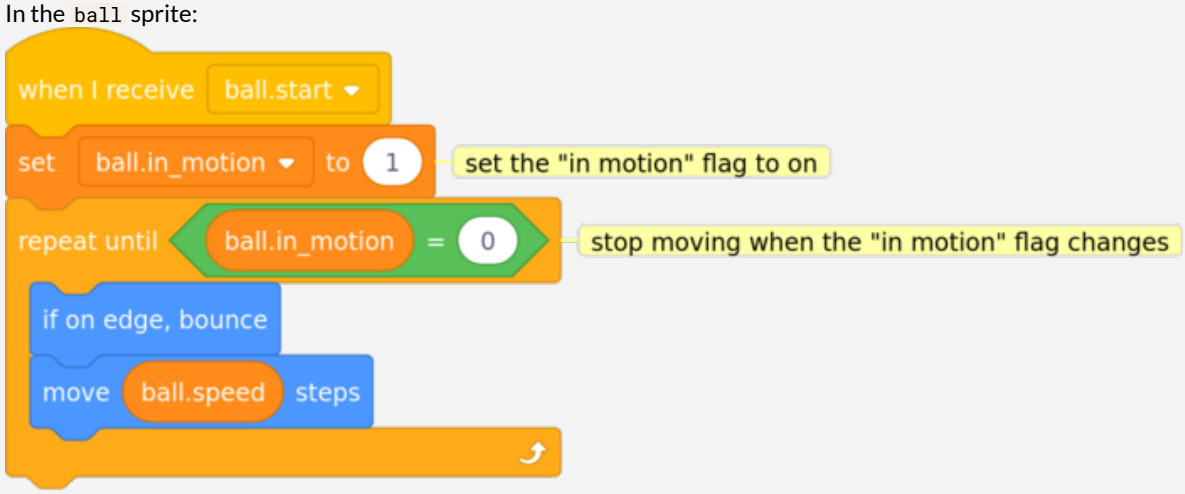
For the movement loop I changed the 

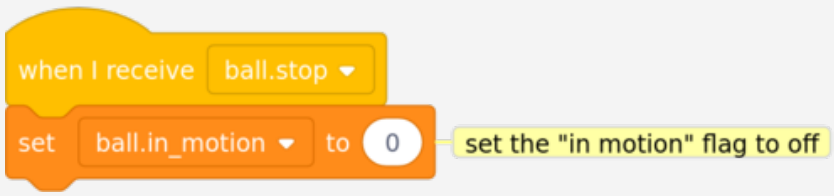
block to a 

block which stops as soon as the `ball.in_motion` flag changes to 0.

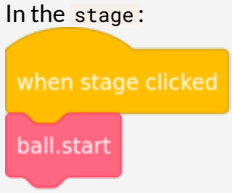
See my code:

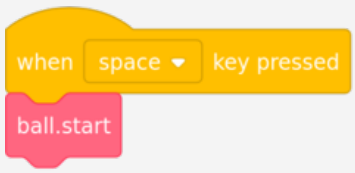
In the `ball` sprite:

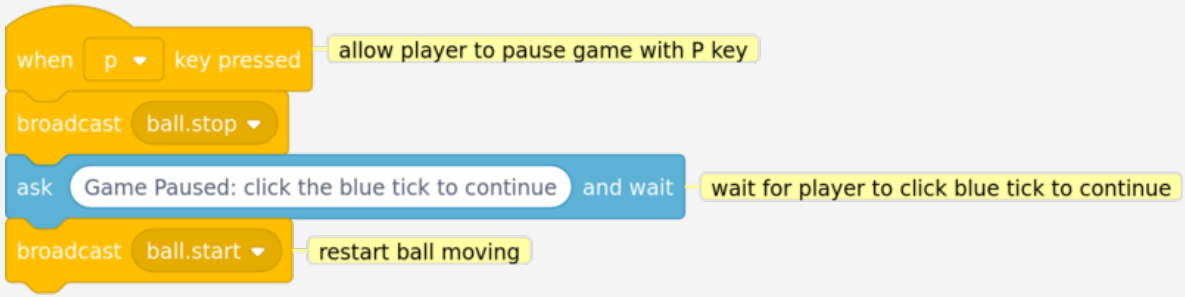




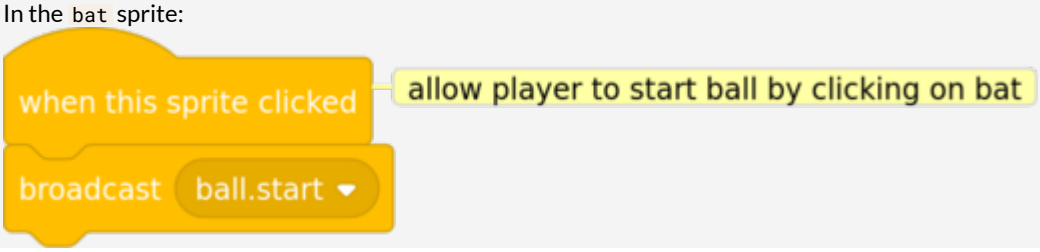
In the `stage`:







In the `bat` sprite:



Test that your code launches the ball when you click the stage or bat, and when you press the space key. Check that pressing the *P* key causes the ball to stop moving.

4.5. Animate the water

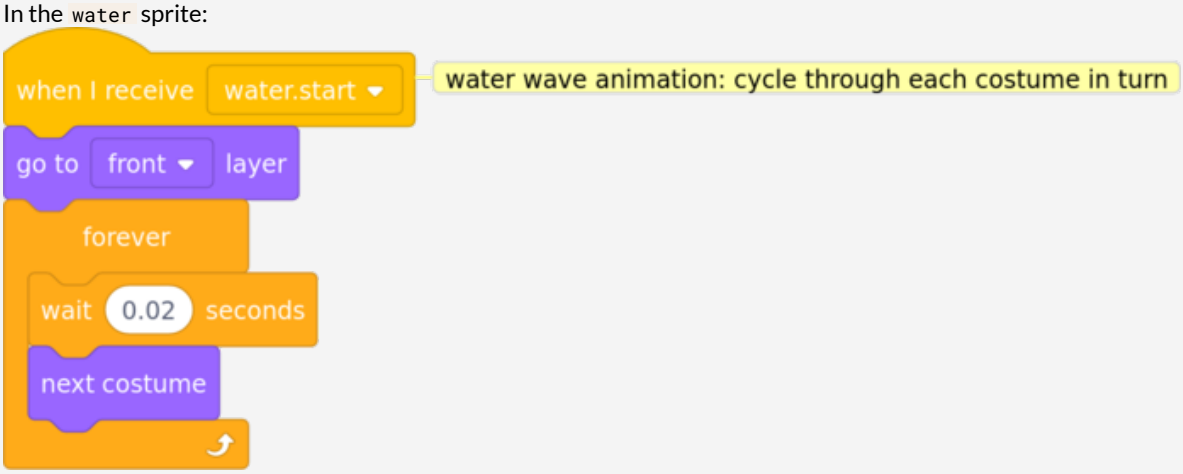
While this is not strictly necessary for the game, I liked the idea of the strip of water at the bottom having a moving wave effect. It's also a nice exercise in creating simple animation effects in Scratch.

Task

Add code to the `water` sprite to cycle through each of its costumes in turn to give the water a moving wave effect. You may need to add a delay between costumes to make the effect look natural: experiment with the length of the delay until you're happy with it. Trigger the animation in respose to an event: I named the event `water.start`.

See my code:

In the `water` sprite:



With a delay of 0.02 seconds between costume changes the water looks as though it has waves gently rippling through it.

Note: I added a `go to front layer` block so that the water will hide the ball if the ball moves behind it, making it appear that the ball has fallen into the water.

In the `stage`:

Don't forget to test your code.

4.6. Build a wall

One way to tackle a complex coding task like this is to break it down into smaller pieces; then you can gradually put the smaller pieces together until the code does what you want. Scratch has a feature to help us do this: we can define our own blocks and use them elsewhere in our code. Let's work through the code to build the wall together, step by step.

How do you build a wall? First, you lay a row of bricks end to end. Then you lay another row on top of the first row, and so on until the wall is as high as you want it.

So first, we want to write a block of code to lay one row of bricks — let's call that `build_row`. Then, once we've written and tested that block, we want to write another block which runs (we say *calls* in coding) `build_row` several times to create a wall of several rows: every time it calls `build_row`, another row of bricks will be added to the wall.

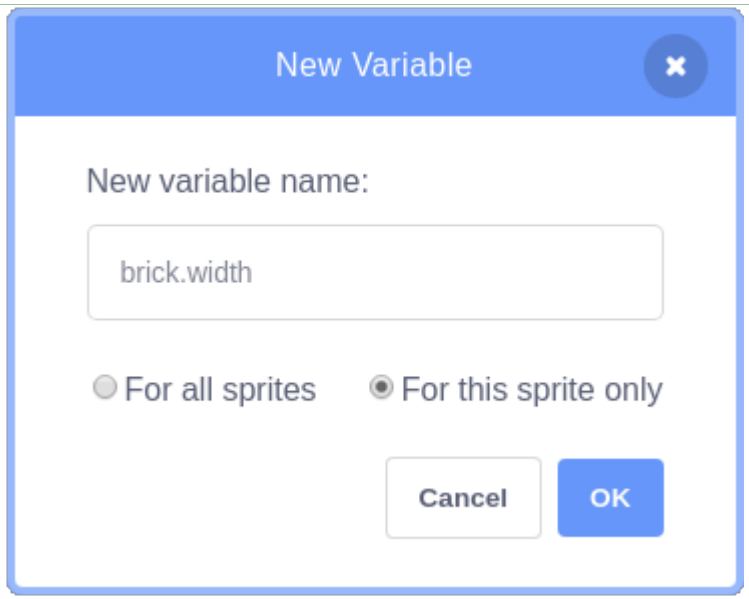
In order to place our bricks side by side, we need to know how wide one brick is. Remember I said earlier that our `brick` sprite is 40 pixels wide by 24 high? Those measurements are going to be crucial to our building, as all the wall's measurements will be derived from them. They're so important that I'm going to store them in variables (see page 73). This will make it much easier to change the brick size later on if we decide to (you might think my basic brick sprite looks nothing like a brick and want to design your own of a different size).

When do we want to build the wall? We know that it needs to be at the start of the game, before the player launches the ball, but as we don't yet know precisely, the most flexible way is to start building in response to a message. Let's listen for the message `game.build_wall` before we start building.

Task

In the `wall` sprite, create two variables named `brick.width` and `brick.height` to hold the width and height of a brick (in Scratch, we do this by using the *Make a Variable* button under the 

category). Only the wall needs to know about brick size, so we can make the variables *private* or *local* [https://en.scratch-wiki.info/wiki/Variable#Local_Variables] to the `wall` sprite, so that only the `wall` can see them or make changes to them. Scratch calls this option **For this sprite only**.



Create a new private variable

In general it's a good idea to keep variables as private as you can: it avoids them being accidentally changed by other parts of your code. In coding this principle is called encapsulation [https://en.wikipedia.org/wiki/Encapsulation_(computer_programming)].

Scratch will set the values of our variables to zero. We need to change these to the correct width and height before we start building, so write some code to do this. I chose to put my code into a block to keep it tidy and in case I want to add any more setup code later.

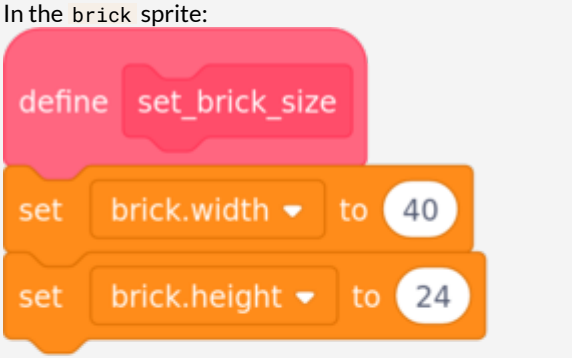
To create a scratch block:

1. go the  category

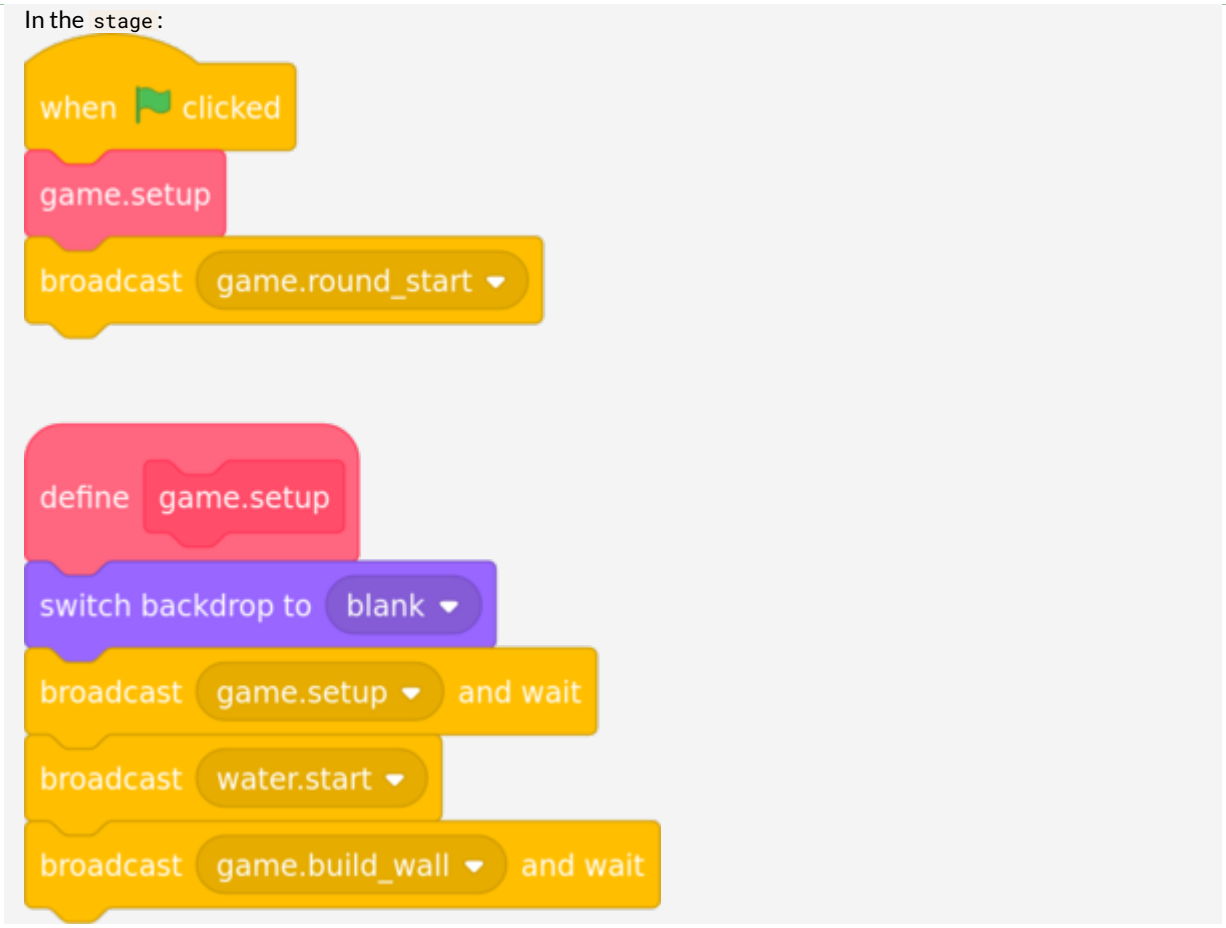
2. click *Make a Block*
3. type a name for the block: I used `set_brick_size`
4. click *OK*

See my code:

In the `brick` sprite:



In the `stage`:



You can check that Scratch has set the variables to the correct values simply by clicking on the variable at the left side of the screen: Scratch will show you the current value of the variable. This is very useful when testing. Has your code set the values of `brick.width` and `brick.height` correctly?

That was easy, wasn't it? Next we need to write a block to lay a single row of bricks.

4.6.1. block `build_row`

Let's create a new block (also in the `wall` sprite) named `build_row`.

The block needs to do something like this:

1. start at the left edge of the stage
2. repeat these steps:
    1. place a new brick
    2. move one brick's width to the right (or a bit more than a brick's width if we want a gap between our bricks)
3. stop when we get to the right edge of the stage

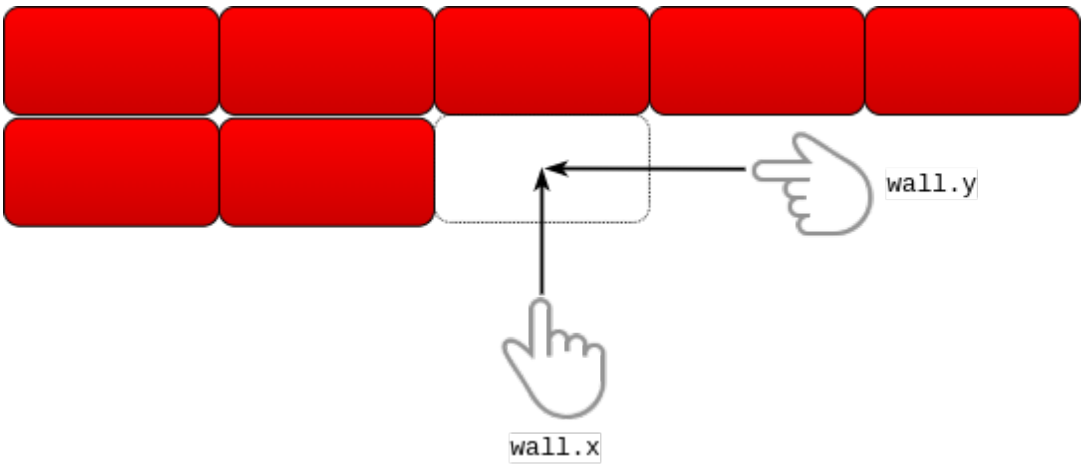
I'd like to introduce a couple of general coding terms at this point:

A loop (see page 72) is simply a section of code that repeats more than once. In this case we repeat the steps of placing a brick and moving along the wall.

An outline of what a piece of code is supposed to do, such as the steps outlined above, is called an algorithm (see page 72): a set of steps the computer should follow to complete a task.

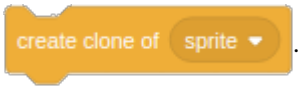
You may have spotted that the code will need to keep track of where the last brick was placed (how else does it know where to put the next brick?). And wherever code needs to keep track of information we can use variables.

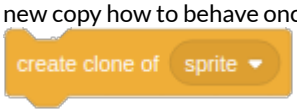
I created two variables named `wall.x` and `wall.y` (this time for all sprites because the `brick` sprite needs to be able to see them too) to store the *x* and *y* position on the stage where we want the next brick to go. I think of them a bit like fingers pointing to a position on the stage telling the wall where to put the next brick.



Variables `wall.x` and `wall.y` point to the position of the next brick

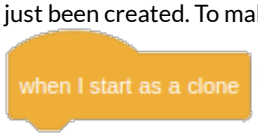
I think the trickiest part of this code is actually creating a new brick and putting it in the right place, so I'm going to explain that in a bit more detail. If you already feel confident enough to try writing your code, feel free to skip the next few paragraphs and jump straight in.

In Scratch, we make copies of a sprite by using the block 

. What makes it tricky is telling the new copy how to behave once it's been created. Your first instinct might be try adding code after the 

block but that won't work: the only way to get a sprite to change its position is for the sprite to move itself.

Do you recall how do we ask a sprite to do something? We broadcast a message, and get the sprite to listen out for that message.

Now, when we create a clone of a sprite, Scratch automatically sends the new clone a special message to tell it that it's just been created. To make the sprite act on that message, we write code in that sprite under the 

hat block. So we'll also need to add some code to the `brick` sprite to tell it to move the right place after it's been cloned.

Task

First create the `wall.x` and `wall.y` variables (remember to select **For all sprites**), and then have a go at writing the code for the `build_row` block.

Hint: in Scratch, the *x* and *y* properties of a sprite refer to the point at the *centre* of the sprite. So if we want our first brick to be placed at the left edge of the stage, we need to set `wall.x` to a value which is half a brick's width to the right of the left edge. You might need to use some trial and error to get the start of the row in the right place and to work out when to stop building.

Note: my first attempts at writing my code contained a bug (see page 72). A bug is simply a coding mistake, something the code does that programmer did not intend.

The type of bug I encountered is known as a race condition [https://en.wikipedia.org/wiki/Race_condition] . This is when the behaviour of one piece of code relies on another piece of code completing first. In my case, I found that my code was changing the `wall.x` variable before the brick's `when I start as a clone` script had finished, and so the brick was put in the wrong place.

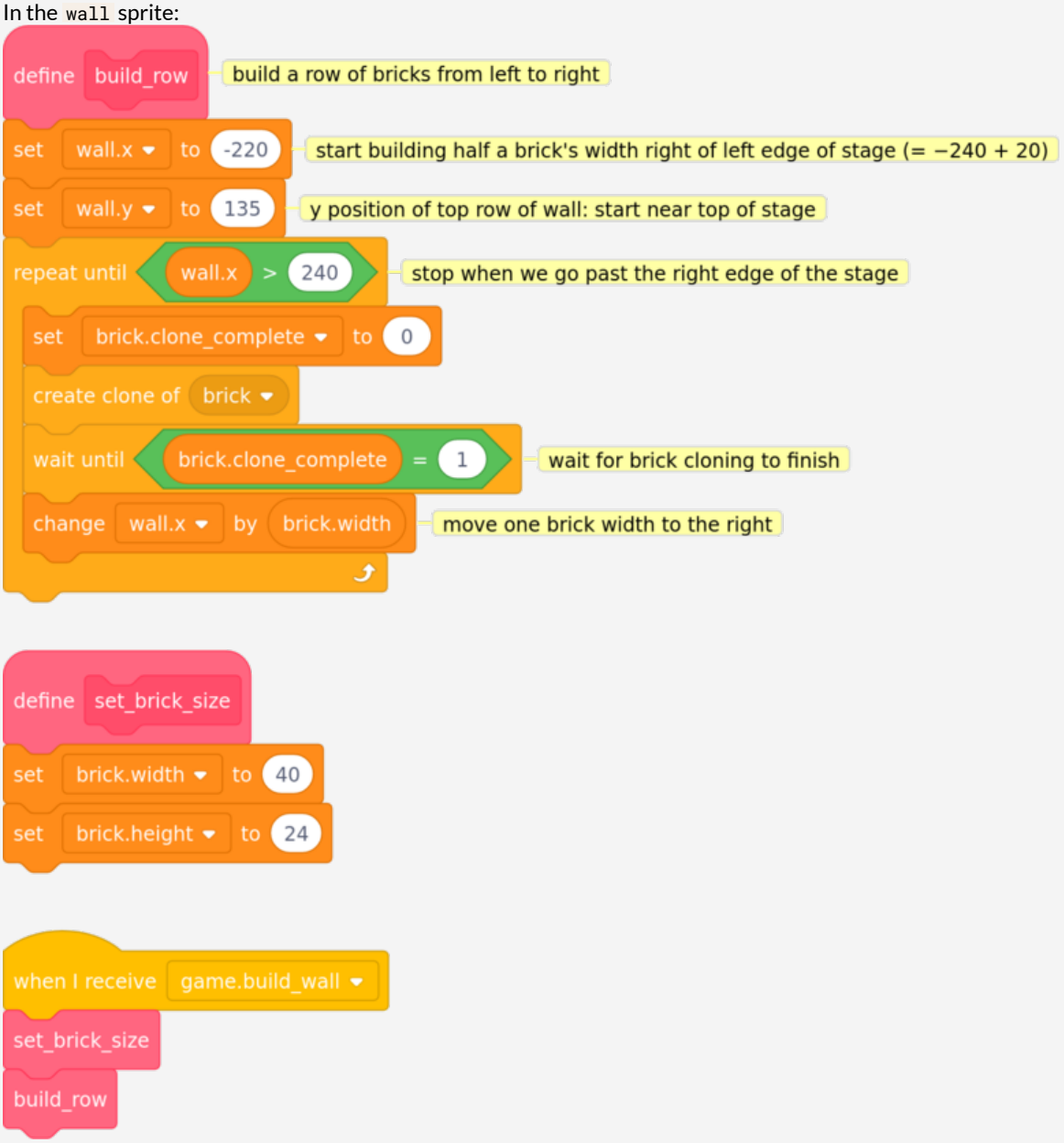
A possible quick fix is to add a small delay after the `create clone` block to allow the clone time to position itself before the `wall.x` variable changes: a wait of 0.01 seconds seemed to be enough. However, this isn't really a robust solution: what if the code were to be run on a much faster computer? The 0.01 second delay may then not be enough.

A more robust solution is to get the clone to signal when it has completed. I decided to use another flag (see page 72) for this which I named `brick.clone_complete`. The code works as follows:

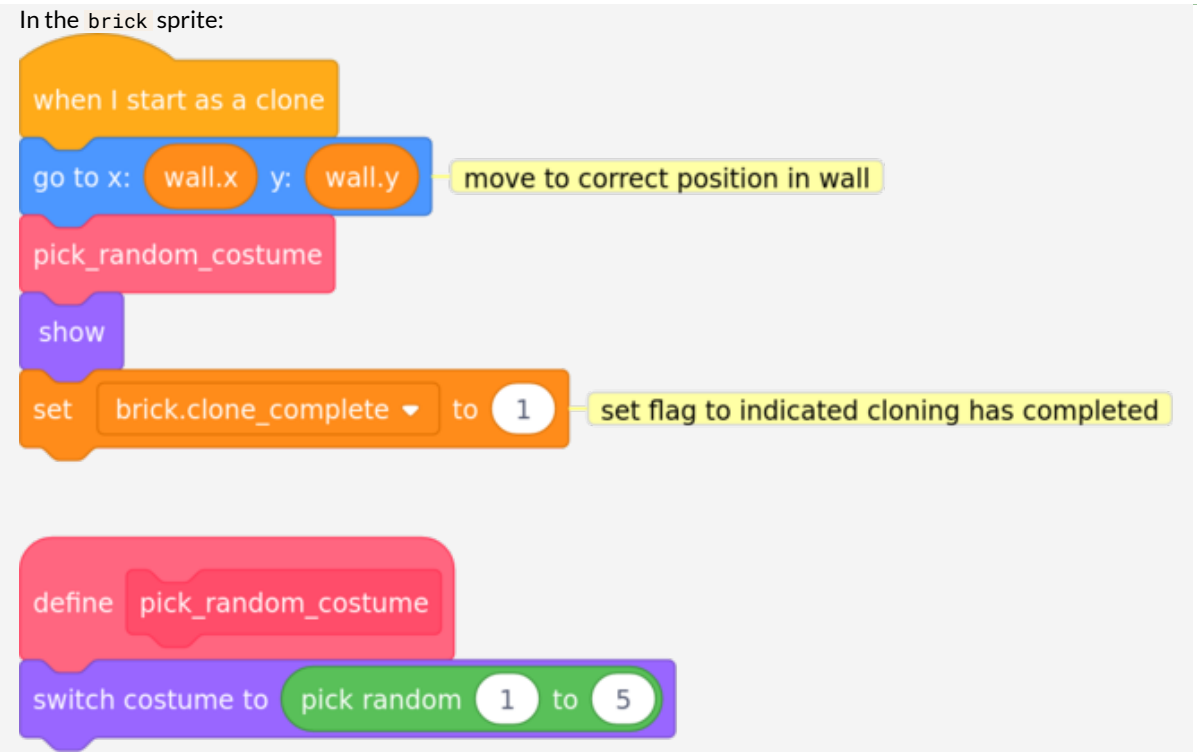
- Before cloning a new brick, the code sets `brick.clone_complete` to `0` (meaning *no* or *is not complete*).
- It then waits until `brick.clone_complete` equals `1` (meaning *yes* or *is complete*) before continuing.
- At the very end of the `when I start as a clone` script, the code sets `brick.clone_complete` to 1.

See my code:

In the `wall` sprite:



In the `brick` sprite:



The advantage of writing code in small blocks is that they are easier to test on their own: just click the block, watch what the code does, and if it's not quite right, alter the code and test again. Keep refining and testing until the code does what you want it to.

If you look at my code above you will see that I added another block to the `brick` sprite named `pick_random_costume`. You can probably guess what the block does from its name — can you see how the code achieves it?

4.6.2. block `build_wall_of_(n)_rows`

Now that we can build a single row of bricks, it's time to use that to build a wall. How many rows of bricks do we want in our wall? I'm having trouble deciding: perhaps to begin with we only want a few rows, say three, but I might change my mind later. Perhaps we may want to have several "levels" in our game and add more rows to the wall as the player progresses through the levels.

There's a useful coding concept that can help us here: parameters (see page 73). A *parameter* is a placeholder for a piece of information (known as a *value*) that you *pass* to a block of code to tell the block more precisely how to behave.

For our wall building block we don't want the number of rows of bricks to be fixed in advance. Wouldn't it be useful if we could write our block so that it could build any number of rows? Well, we can, using a parameter; Scratch calls parameters *inputs*.

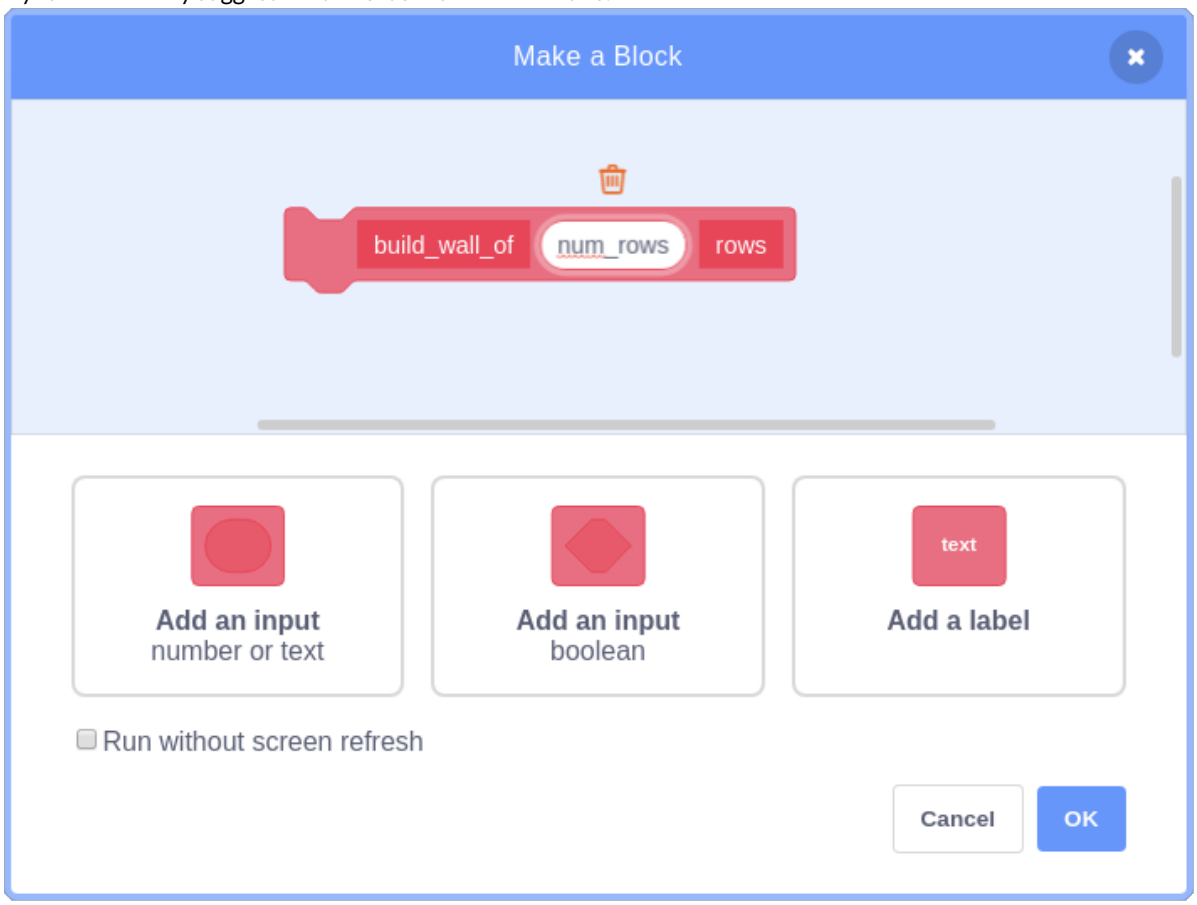
Task

To create a scratch block to build any number of rows:

1. go the 

category
2. click *Make a Block*
3. type the block's name: I suggest `build_wall_of`
4. click the *Add an input: number or text* button to create our parameter; Scratch adds an input box (we want a number input here: the number of rows to build)
5. name the input: I suggest `num_rows`
6. (optional) click the *Add a label* button and type `rows`

If you followed my suggested names it should look like this:



Note: The label "rows" I added at the end doesn't actually do anything in the code: it's purely there to make the name of the block more readable; it means we can write code such as `build_wall_of 3 rows` instead of `build_wall_of 3`.

Once you're happy with your block definition, click OK to create your block. Now it's time to add the code to build several rows of bricks.

Remember that my code in the `build_row` block set a fixed start position for the row? Well that's not ideal: if I call `build_row` twice, it will place the second row at exactly the same place on the stage as the first, and we'll end up with two rows directly on top of one another so that we only see one row. (By all means try calling `build_row` twice to see what I mean.) So that needs to be changed.

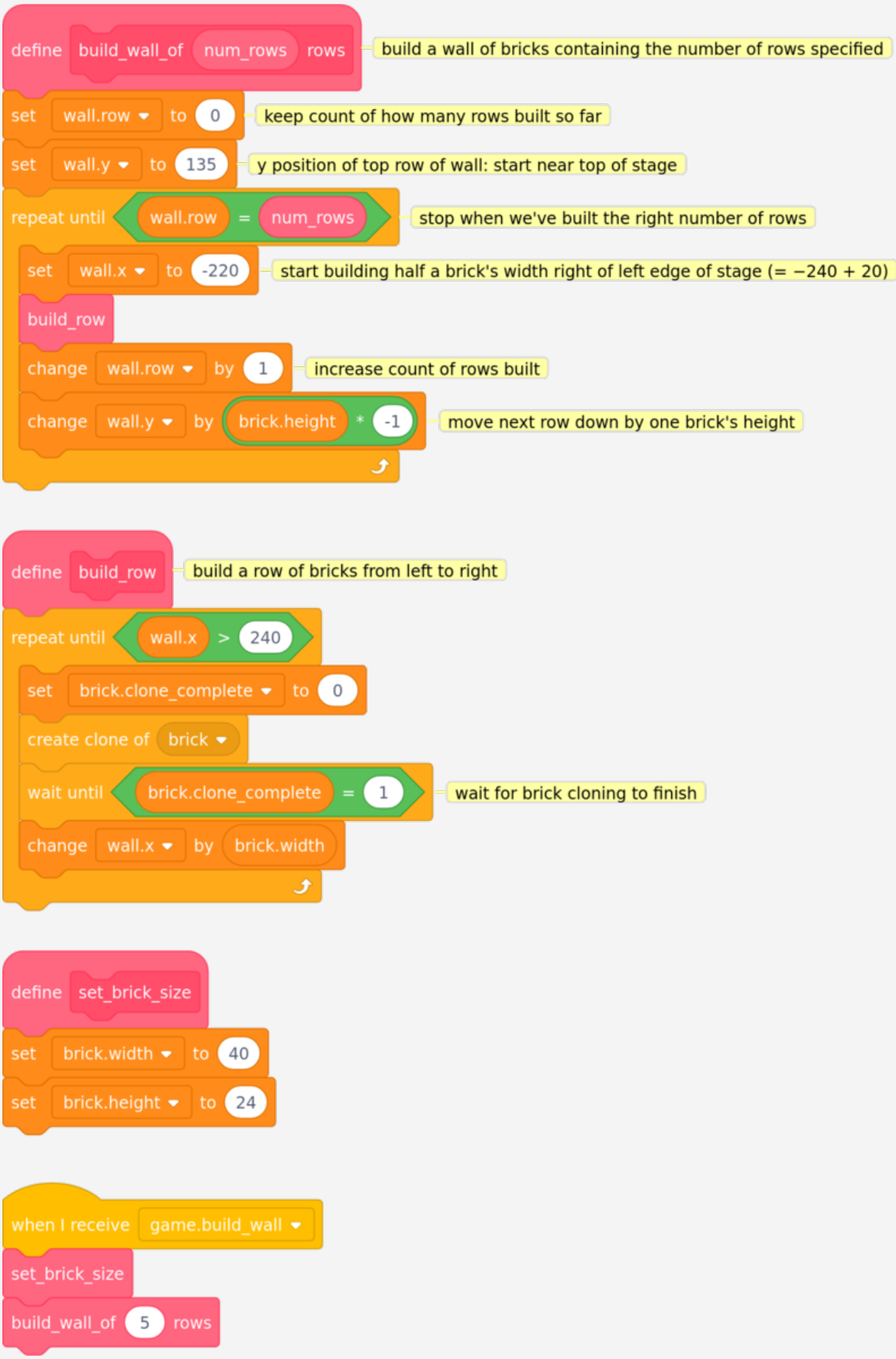
Hint 1

When we want to do the same thing more than once, we usually want to use a loop. If you're having trouble writing your code, start with a simple `repeat` block that calls `build_row` 3 times.

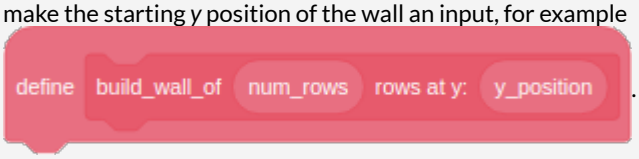
Hint 2

I moved the `set wall.x` and `set wall.y` blocks out of `build_row` and into my new `build_wall_of (num_rows) rows` block.

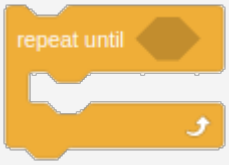
See my code:



As I mentioned above, I moved the `set wall.x` and `set wall.y` blocks out of `build_row`. This makes `build_row` more flexible: it can now start building at any point on the stage we want. We just set `wall.x` and `wall.y` to the start position before we call it.

Note: it is possible to have more than one parameter (see page 73) (input) to a block. We could also make the starting *y* position of the wall an input, for example 

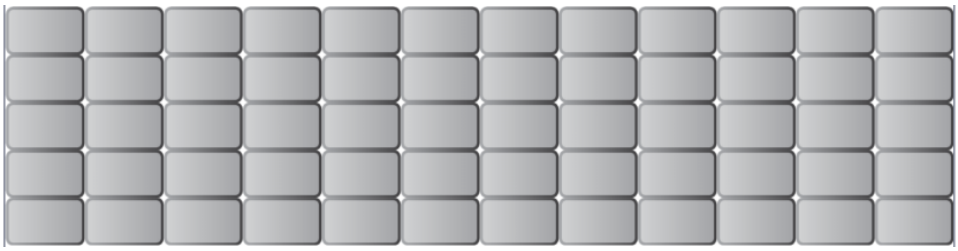
. I chose not to use multiple inputs to keep my explanation simpler, but feel free to use them if you like.

I have also created another variable named `wall.row` (only for the `wall` sprite) to keep count of how many rows have been built so far. Every time I call `build_row` I increase the counter by 1. I use a 

block which compares the counter with the number of rows the block was asked to build (passed in as the input `num_rows` when the block was called); when the counter reaches `num_rows` it stops building.

I decided to build my wall from top to bottom, which is why I have to change `wall.y` by `brick.height * -1`: I need to subtract one brick's height from `wall.y` to move down the stage. It doesn't matter whether you choose to build your wall from top to bottom or the other way around. If you build from bottom to top, you'll need to start further down the stage to leave enough room but you can simply `change wall.y by brick.height` (no need to multiply by −1).

Here is how the resulting wall looks if I specify 5 rows:



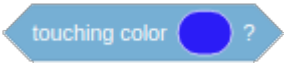
Result of running `build_wall_of 5 rows`

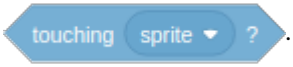
4.6.3. Challenge: offset alternate rows of bricks

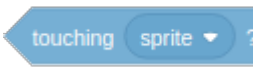
see Challenge: offset alternate rows of bricks (see page 39)

4.7. Detect the ball falling into the water

Detecting when one sprite collides with another is (in theory) straightforward in Scratch, as we have a number of blocks in the 

category to help us, in particular 

and 

. To detect when the ball falls into the water we will use 

.

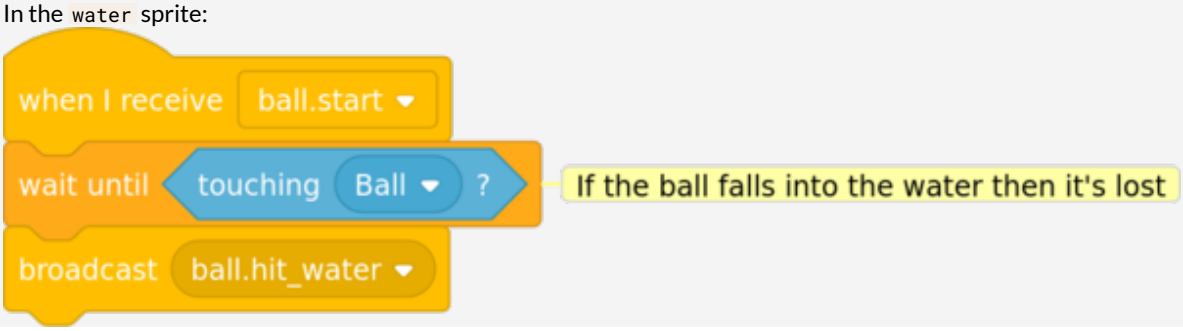
What should the game do when the ball falls into the water? Well, we know that the player will lose the ball, but we don't need to worry about the details just yet. To begin with, let's simply broadcast a message to tell the other sprites (and the stage) what has happened: I called the message `ball.hit_water`.

Task

Write the code to detect when the ball falls into the water and broadcast a message when it does. It doesn't matter whether you put your code into the `ball` or `water` sprite — I chose to put mine into `water`.

See my code:

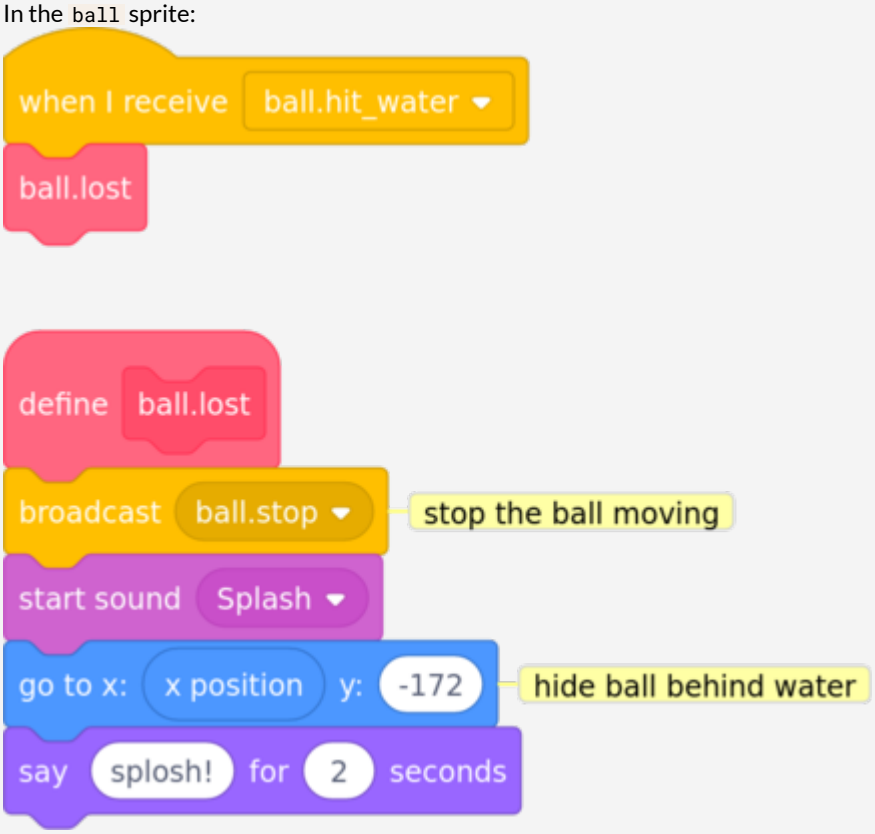
In the `water` sprite:



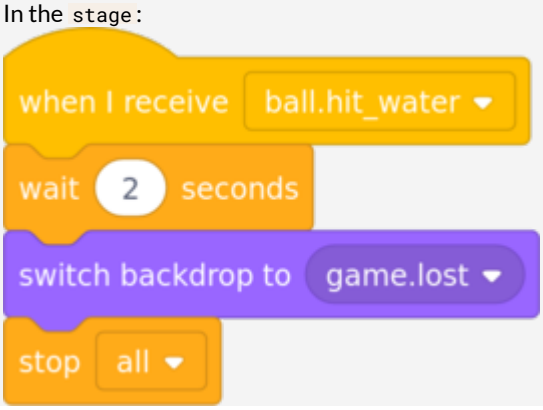
Next we need to decide what the game should do when the ball does fall into the water. My code keeps it very simple, but there is plenty of opportunity here to use your imagination, so let's see what you come up with.

See my code:

In the `ball` sprite:



In the `stage`:



Time to test your code: does it detect when the ball falls into the water and show the "game over" backdrop?

4.8. Detect the bat hitting the ball

We know how to detect when one sprite touches another. But should we put the detection code in the `bat` sprite or the `ball` sprite?

Well, it's the ball that has to take action (change its direction), but actually it doesn't matter where we put the collision detection code if we make use of messages. I decided to put my code in the `bat` sprite; it seemed tidier that way, as the `ball` sprite will probably end up with more code in it (because the ball can hit a lot of different things, and has to start and stop etc). So I detect the collision in the `bat` sprite and broadcast a message when the ball hits it.

Why bother with messages? Why not just get the ball to detect when it hits the bat and then change its direction? That would work, but there are several other reasons why I chose to broadcast a message:

- It's more flexible: a message can be picked up by any number of sprites, and each sprite can take different action in response.
- It keeps the collision detection code block small, simple and readable. In coding, simple is usually preferable: simple code is easier to read and understand, and there is less chance of bugs.
- It separates the collision detection code from the action taken as a result. So it will be easy to change the game's behaviour later without changing the collision detection code.

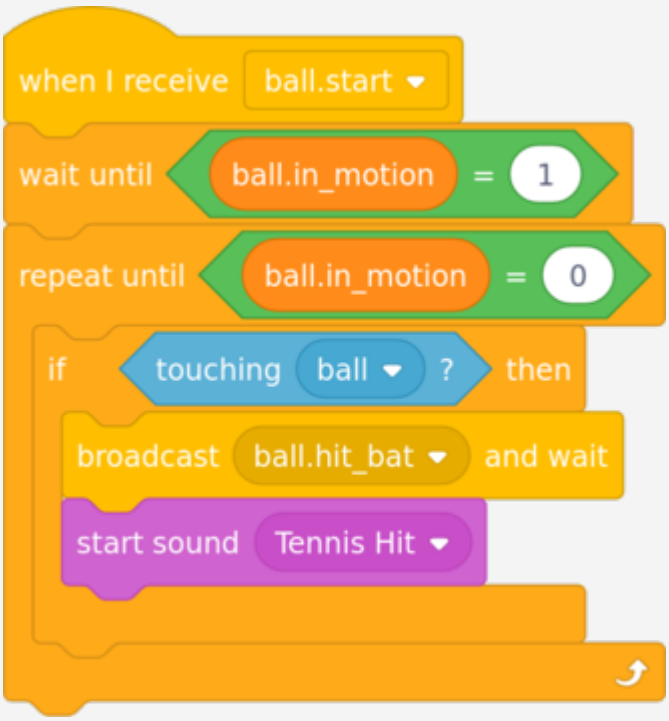
Task

We can now add our collision detection code to the `bat` sprite without having to worry about what the ball should do (we will deal with that problem next).

Note: I encountered another race condition [https://en.wikipedia.org/wiki/Race_condition] bug while writing this code. My code is supposed to start when it receives the `ball.start` event and keep running until the ball stops moving (detected by checking the state of the `ball.in_motion` flag). However, I found that the `repeat until ball.in_motion = 0` block ran before the `ball` sprite had had time to set the `ball.in_motion` flag to `1`, and was therefore exiting immediately, which meant that the bat didn't detect any collision with the ball.

Once I realised what was going on, the fix was simple: get the script to wait for the `ball.in_motion` flag to be set before entering the loop.

See my code:



Once the ball starts moving, keep checking if it touches the bat. When it does, broadcast the message `ball.hit_bat`. I also added a simple sound effect.

Test that the ball detects when it hits the bat and plays the sound.

Now we can move on to thinking about how the ball should react. We know we want the ball to "bounce" or "reverse direction" in some way, but don't yet know how. This often happens when we write code, so let's use a technique that programmers often use in this situation: we'll define a block named `bounce` but leave the definition empty.

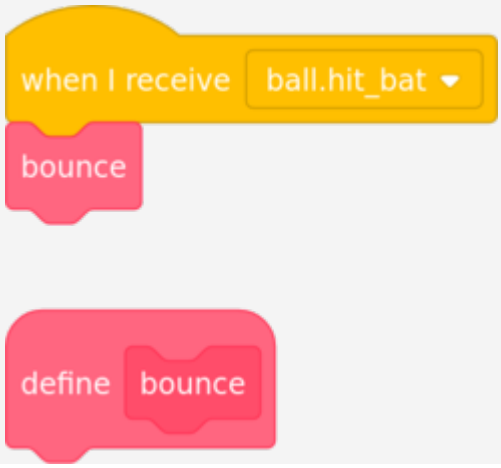
At first glance that might seem odd to you: after all, an empty block doesn't "do" anything. But this technique has several advantages:

- We can concentrate on solving one problem at a time.
- We can lay out the outline structure of our code without worrying about the exact details until later. In other words, we can say roughly what we want the code to do before we think about how.
- It encourages us to write small blocks of code that do one specific thing.
- In this project there are other sprites the ball can bounce off. Perhaps the `bounce` code can be shared?

Task

With that in mind, let's write our template for the "bounce" code in the `ball` sprite.

See my code:

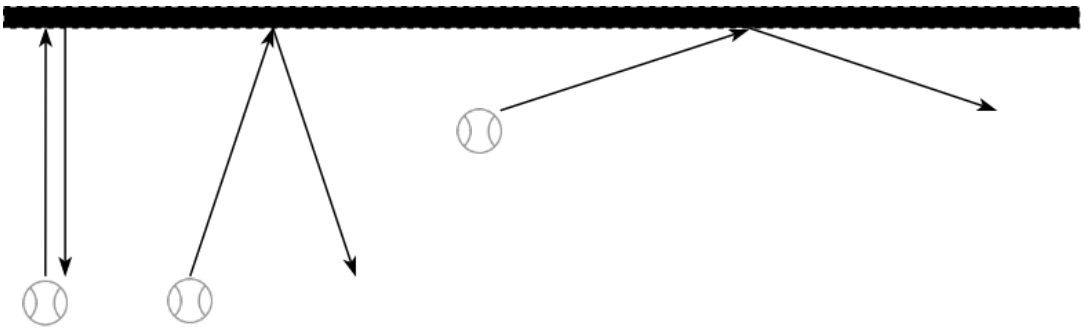


So far, so good. Now let's think about *how* the ball will bounce.

4.8.1. How Does A Ball Bounce?

Have you ever stood in front of a (flattish) wall and thrown or kicked a ball at the wall (away from windows, of course)? If you have, you'll have noticed that the angle at which the ball hits the wall affects the direction it takes as it bounces back.

If you throw the ball straight at the wall at right angles, it comes straight back to you (actually, you can affect that by putting spin on the ball, but let's ignore that to keep this explanation simpler). If you kick the ball at an angle, it comes back off the wall at the same angle. Here's a diagram showing what I mean:



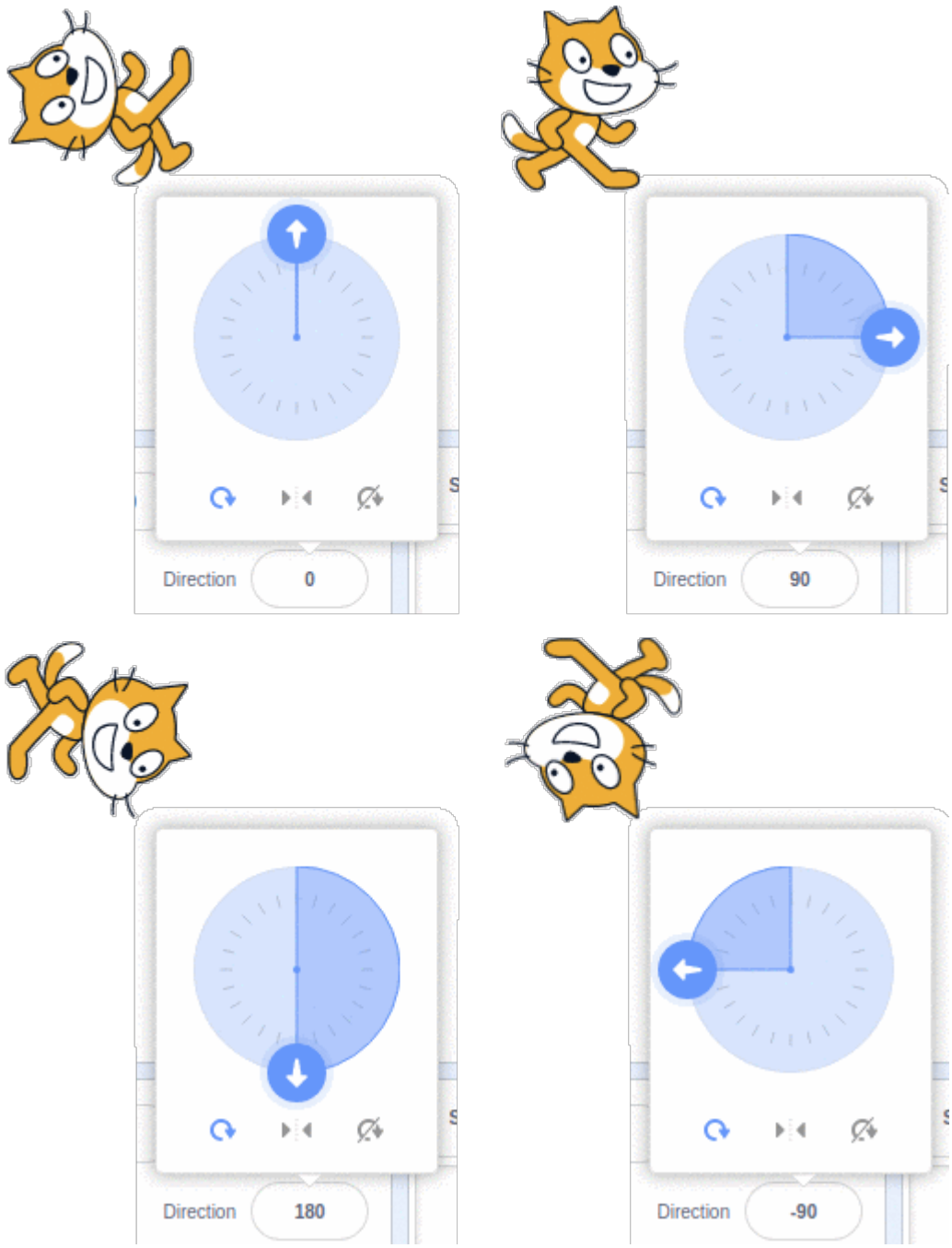
How a ball bounces off a wall

4.8.2. Direction in Scratch

In Scratch each sprite has a direction [https://en.scratch-wiki.info/wiki/Direction_(value)] which tells the sprite which way it is facing and in which direction it will move. Scratch's direction value is very like a compass bearing:

- direction 0 means pointing straight up (north on a compass)
- direction 90 means pointing to the right (east)
- direction 180 means pointing straight down (south)
- direction −90 or 270 means pointing to the left (west)

Here is a diagram showing Scratch Cat [https://en.scratch-wiki.info/wiki/Scratch_Cat] facing north, south, east and west.



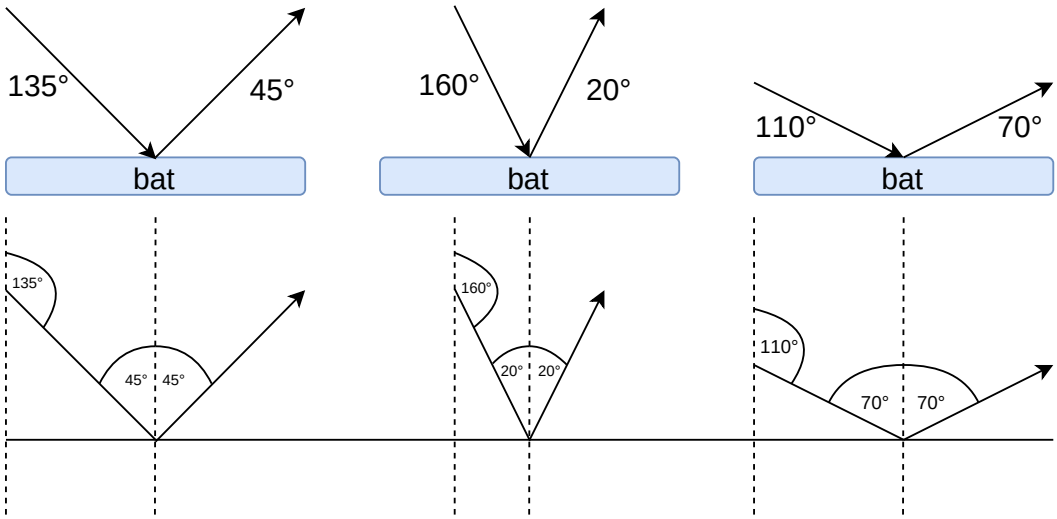
Scratch Cat facing the four main compass directions

To get a better idea of how the direction value affects a sprite, try this:
Add the `Arrow1` sprite from the Scratch library to an empty project and click on the `Direction` value.
Drag the direction arrow around and watch how the direction value and the arrow changes.

4.8.3. Getting the ball to bounce

In order to calculate how our ball should behave, we're going to need to use some geometry. If you find this section a bit difficult, don't worry: you can always skip it and just use my code. But for those of you who are interested, I wanted to explain how the code works. So, let's take a deep breath and dive in.

Below is a similar diagram to the "wall" diagram above, this time with the ball approaching and bouncing off the bat at different angles. For simplicity, I assume the ball is travelling down the stage and then hits the top edge of the bat. (Most of the time that's what will happen, but it is possible for the ball to hit the sides of the bat, and even the bottom edge. But let's worry about those particular wrinkles later.)



Direction of the ball as it bounces off the bat

On the left of the diagram, the ball is travelling in a down-and-right direction (south east on a compass, direction=135 in Scratch). It hits the horizontal bat at an angle of 45° to the vertical and comes back off the bat at 45°.

In the centre of the diagram, the ball is coming down at a steeper angle (direction=160); it hits the bat at 20° to the vertical and bounces off at 20°.

On the right of the diagram, the ball is approaching at a much shallower angle (direction=110); it hits the bat at 70° to the vertical and bounces off at 70°.

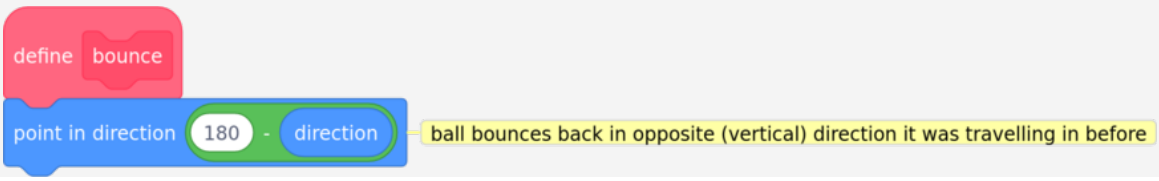
Again, the ball always bounces off the bat at the same angle that it hits the bat. If you look at the ball's starting direction and its direction after bouncing, you may notice a pattern: the start direction and direction after bouncing always add up to 180°. This gives us a way to calculate which direction the ball should travel after it hits the bat. We can describe it as: "new direction is 180 − starting direction". And that can be translated directly into code.

Task

Time for you to have a go!

See my code:

In the `ball` sprite:



Now test that the ball bounces off the bat back up the stage.

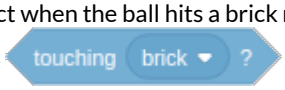
4.9. Detect the ball hitting a brick

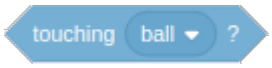
When the ball hits a brick, the following things should happen:

- the ball should bounce off the brick
- the brick should break and disappear

Notice that the bouncing aspect is very similar to what happens when the ball hits the bat. Whenever our code needs to do something similar to what it's already doing, we should think: can I reuse my existing code? We already wrote a block named `bounce` in the ball sprite which tells the ball how to bounce off a horizontal surface: we can probably reuse it again here.

This is a principle known as *DRY* which stands for *Don't Repeat Yourself* [https://en.wikipedia.org/wiki/Don't_repeat_yourself] . It states that rather than repeating sections of code, we should put the repeated code into a reusable block and call that block each time it's needed.

The code to detect when the ball hits a brick must go in the `brick` sprite. There are many copies of `brick` and if we used the sensing block 

in the ball sprite, the ball wouldn't know which of the many copies of `brick` it was touching. If we place the sensing block 

in the `brick` sprite, each individual brick will share that code and so it will be able to tell when it has been hit by the ball and act accordingly (e.g. change its costume to indicate that it's broken, and then delete itself).

When the brick disappears, we also need to check if it was the last brick. If it was it would mean that the player has won the game, or the round if we extend the game to have multiple "levels", and so we need some way of telling if this brick was the last brick and a way to notify the game if it was.

You probably won't be surprised to learn that my solution to the second part is to broadcast a message: I named it `game.round_completed`. (I anticipate we may need more messages that relate to the game as a whole, hence I'm starting the message name with `game`.)

Again, I have provided some further hints in case you get stuck:

Hint 1

To answer the question *"has the last brick been broken?"* we first need to ask *"how many bricks are left?"* And the obvious solution to that is to count them.

Hint 2

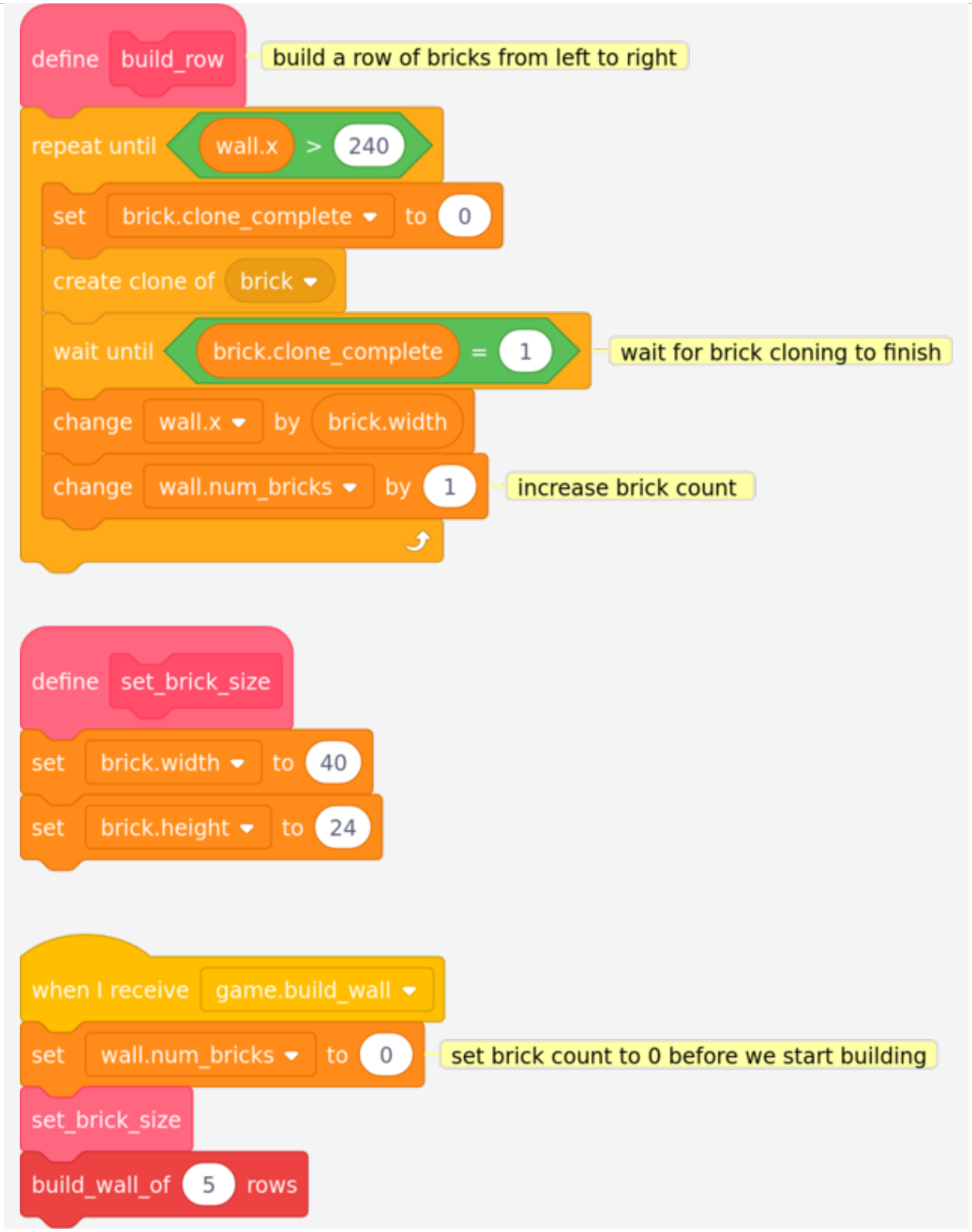
When we build the wall, we could count how many bricks we use; and every time the player knocks out a brick, we could decrease the count by 1. When the count reaches zero, there are no more bricks remaining and the player has won.

Task

First, update the wall building code to keep track of the number of bricks.

See my code:

I am using a variable called `wall.num_bricks` to store the count of the number of bricks in the wall, available to all sprites as it will need to be decreased by the `brick` sprite.



Now let's test the code we just wrote. Testing small blocks of code in isolation like this makes it much easier to find and fix bugs than if we waited until the whole program was finished.

To test my code I followed these steps:

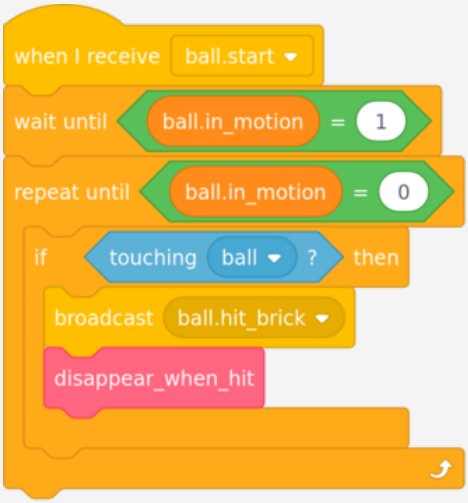
1. Make the variable `wall.num_bricks` visible by placing a tick beside it in the variables category.
   It is then shown on the stage. Drag it to a corner of the stage out of the way.
   You can double-click it to change its style: mine looks like this: wall.num_bricks 0

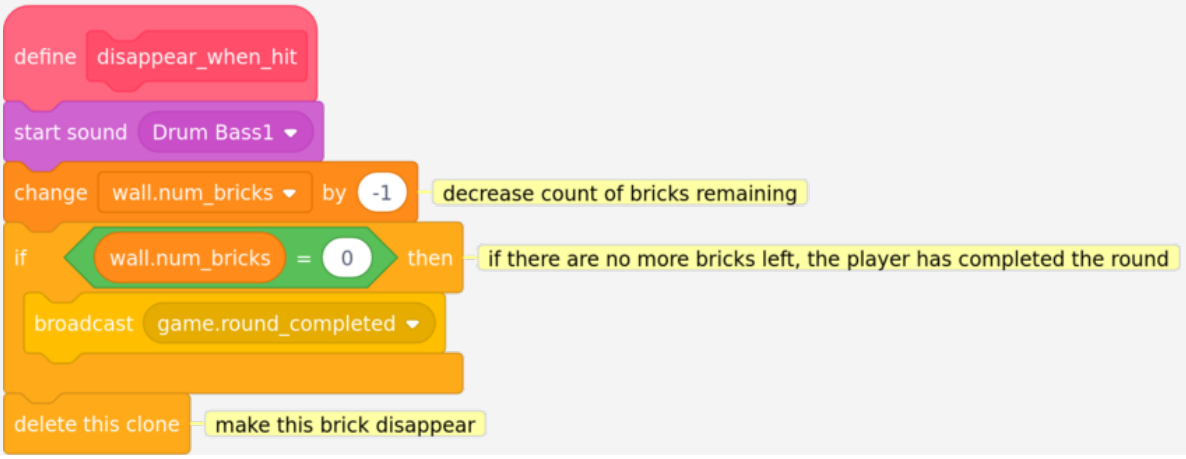
2. Set the wall to build just one row; click the green flag to start building the wall.
    - Check that the `wall.num_bricks` counter is correct: does it match the number of bricks in the wall? If you're using my brick size, there should be 12.
3. Now set wall to build 2 rows and click the green flag. Repeat the same test:
    - Check that `wall.num_bricks` matches the number of bricks in the wall (for my brick size: 24 bricks)
4. Repeat the same test using different numbers of rows of bricks in the wall. Does is work correctly with 3 rows of bricks? 5 rows? You should also test your code with zero rows of bricks. Does `wall.num_bricks` equal zero as it should?

Task

Secondly, add code to the `brick` sprite to sense when a brick is hit by the ball and act accordingly.

See my code:

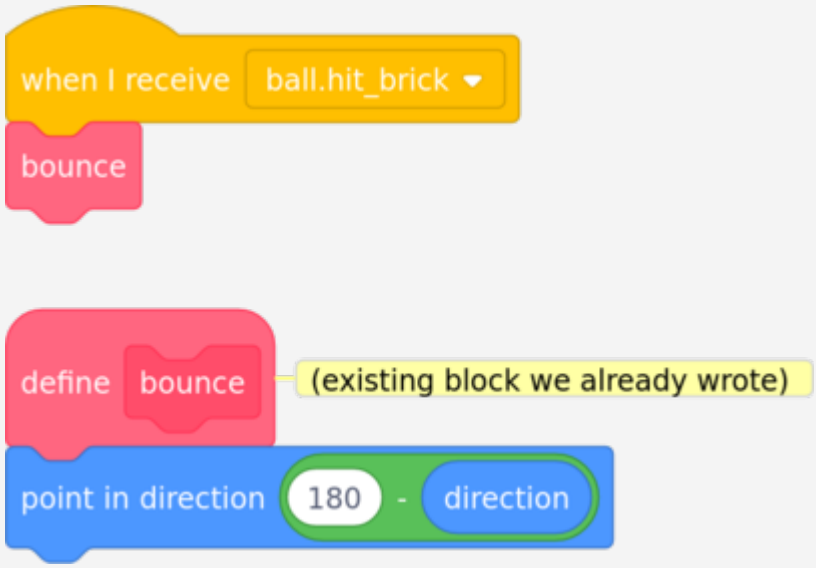




Task

Thirdly, we need to add code to the `ball` sprite to make it act appropriately when it has hit a brick.

See my code:



Notice that I have simply called the `bounce` block we wrote earlier, following the *DRY* principle.

Now test your code again:

- Set the wall to build one row as before; click the green flag to build the wall.
    - Check that `wall.num_bricks` counter is still correct.
    - Start the ball moving and check that:
        1. the ball bounces off bricks correctly
        2. the `wall.num_bricks` counter decreases for every brick knocked out of the wall
        3. `wall.num_bricks` reaches zero when the last brick is broken
- Now set wall to build 2 rows. Again, check that the counter decreases to zero when the last brick is knocked out.
- Repeat the tests using different numbers of rows of bricks in the wall.

Once you're happy that everything is working as it should you can move on to the next section.

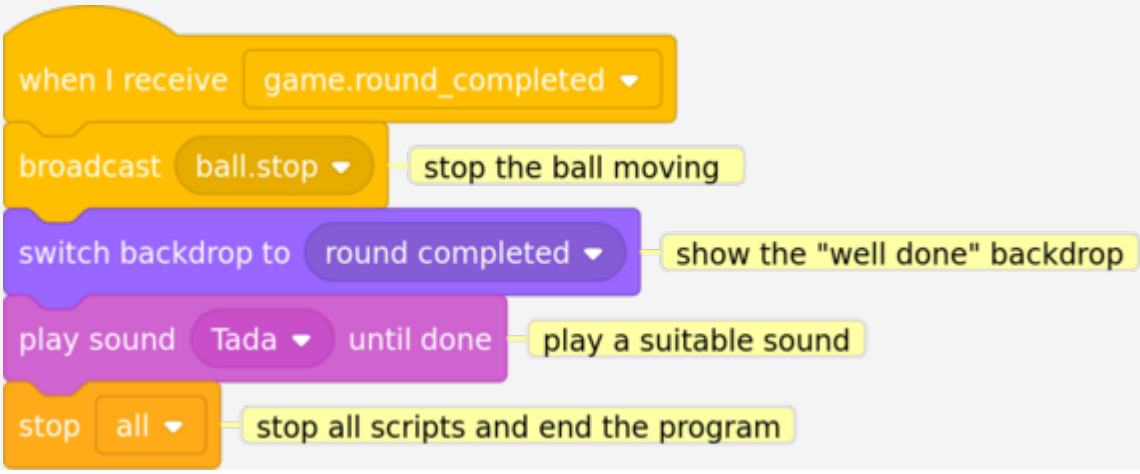
4.10. Has the player demolished the whole wall?

In the previous section we already wrote the code that detects when the last brick is knocked out of the wall, and if so, broadcasts a message. We now need to write the code to listen for that message and act accordingly.

Task

Write your code to listen for the `game.round_completed` message and then inform the player that he/she has completed the round. As this code relates to a game event, I put my code in the Stage. I have kept it fairly simple, but feel free to get creative and extend this however you like.

See my code:



The easiest way to test that your code works is to set the `wall` to build only one row of bricks, then play the game and knock out all the bricks. If you're having difficulty, you can always reduce the value of `ball.speed` to slow the game down.

4.11. Basic game completed

That's it! We have completed the basic version of our game, so well done for making it this far. As it stands the game is quite fun to play (well, I think so anyway) and we can make it harder (or easier if you prefer) by simply tweaking a few values in our code.

For example we could:

- add more rows of bricks to the wall by changing the value of the `num_rows` parameter we pass to the `build_wall_of n rows` block in the `wall` sprite
- make the ball move faster by changing the value of the `ball.speed` variable
- make the bat smaller by changing the size of the `bat` sprite (original size = 90)
- move the wall further down the stage and/or the bat further up the stage so they are closer together, which would give the player less time to anticipate where the ball will go. (original wall start at y=135, bat y=-135)

If you're interested in improving the game, read on for some more ideas and challenges.

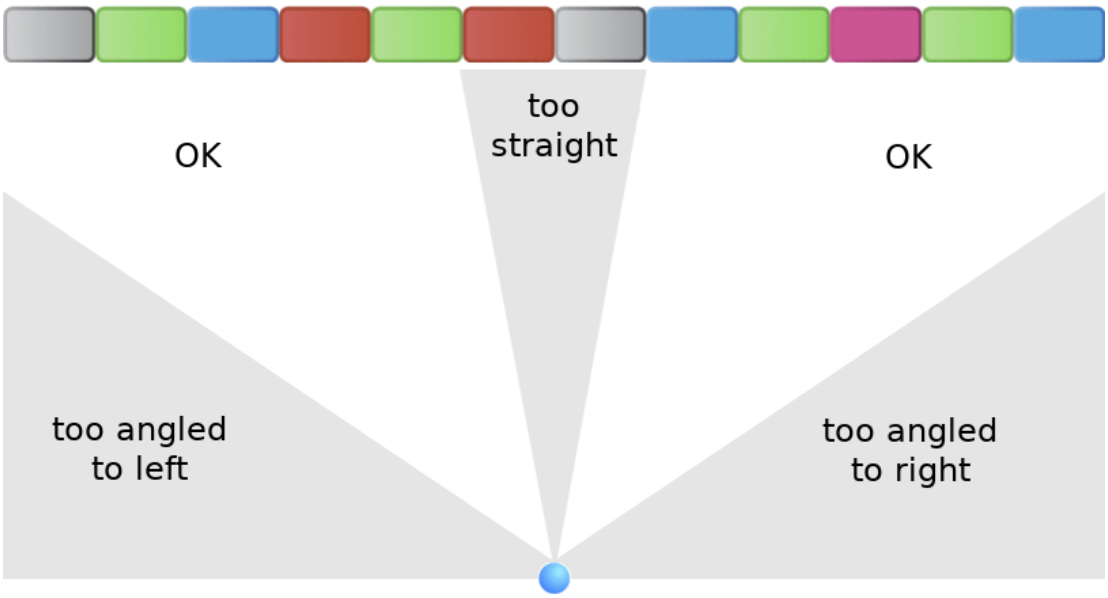
5. Challenges

This chapter contains a number of challenges to add new code and new features to the game. The first few challenges are linked from the main text, but the later ones stand alone.

5.1. Start the ball moving in a random(ish) direction

When launched, the ball always starts moving in the same direction, which can make the gameplay almost identical each time it's played. This means the game can quickly become tedious and samey for the player. It would be much more interesting if the ball started off in a different direction each time it's launched, so let's introduce some randomness to the ball's starting direction.

We need to be careful not to make it too random. If the ball launched straight up, it would bounce vertically up and down all day and the player could never complete the round. Likewise, if the ball launched horizontally, it would bounce left and right all day, never hitting any bricks (or the bat) — the player would be left as a spectator. So we need to limit the range of starting directions we allow. We want the ball's starting direction to be somewhere between *"up and left"* and *"up and right"* but not *"straight up"*.



Suitable starting directions for the ball

Task

Add some code to choose a (sensible) random starting direction for the ball. I have provided some hints if you need them. Click or tap on each hint in turn until you find one that (I hope) helps you. I've given you the first hint for free.

Hint 1: I strongly suggest you create a block to hold this code.

Hint 2:

Recall that direction `0` in Scratch means straight up (refer to the section Direction in Scratch (see page 29) for more detail). Direction `-90` means left; direction `90` means right.

Use these numbers to decide on a sensible range for your starting direction: what is the most *left-ish* direction you will allow? And what is the most *right-ish*?

Use trial-and-error testing in Scratch to experiment: set the ball's direction manually to the value you want to test and start the game. Is the game playable with that starting direction? Is is too hard? Is it fun?

Hint 3:

Once you've decided on the outer limits of the range of directions you will allow, think about what directions are too *straight up and down*. Again, experiment by setting the ball's direction and starting the game.

Hint 4:

After some trial and error, I decided that the most *left-ish* direction I will allow is `-65` and the most *right-ish* is `65`. I then decided that anything between `-15` and `15` is too straight to be allowed.

You may well decide on different numbers, but if you treat the *up and left* and *up and right* directions the same, you will end up with the left limit being the negative (the equivalent minus number) of the right limit as I have.

Hint 5:

You'll need to use the 

block in the 

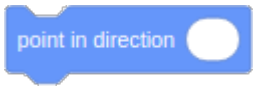
category to obtain a random direction.

There a couple of different ways you could approach this.

1. You could pick a random number between the outer limits you have chosen and then adjust it if it's too straight.
2. You could choose a side, left or right, and pick a random number between the straightest direction allowed and the most angled. For example, if on the right side the allowed direction is between `15` and `65`, you could pick a random number between `15` and `65`; let's say for example `27` is chosen. Then choose at random whether to keep the number positive or make it negative, in other words whether to keep it as `27` or make it `-27`.

I have included example code for both options below.

Hint 6:

Use the 

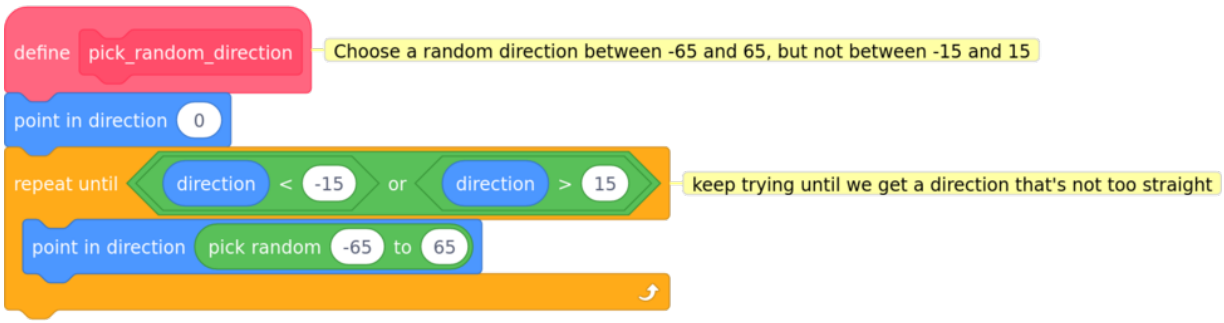
block in the 

category to set the ball's direction. To check what direction it has, use the 

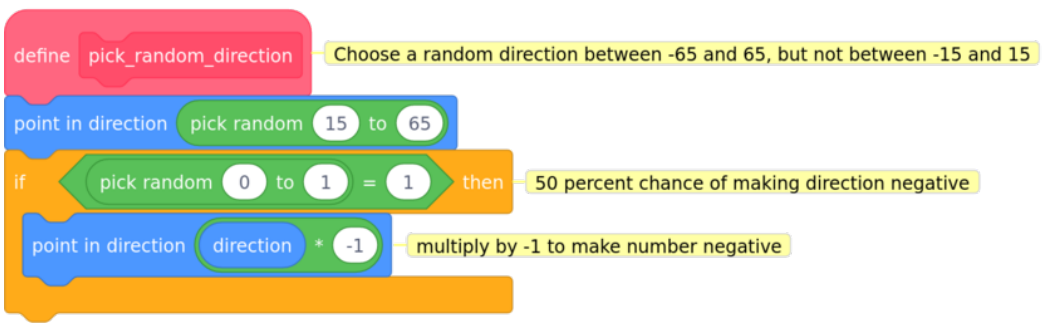
block.

See my code:

Method 1



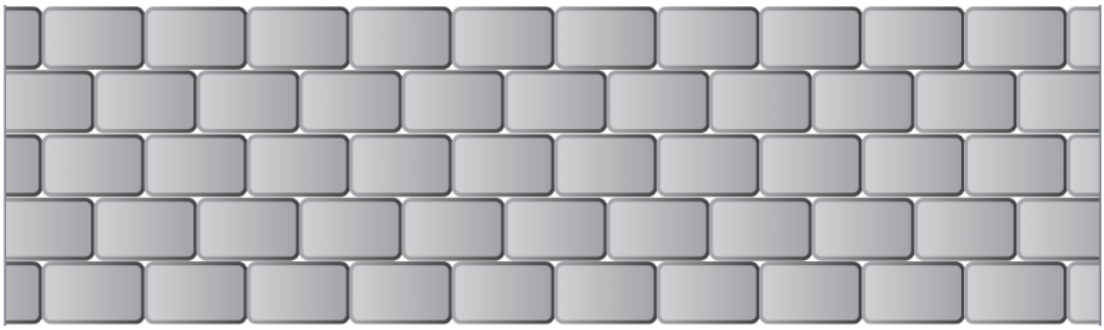
Method 2



Testing code that generates random numbers can be tricky because it behaves differently each time it's run. I found the simplest way to test my code was to select the `ball` sprite, click the green flag to start the program and watch the direction value change. I tested my code at least ten times to make sure that the `ball`'s direction value always fell within the range I had chosen.

5.2. Offset alternate rows of bricks

I want to "stagger" or offset alternate rows of bricks in the wall by half a brick's width so that each brick overlaps the join between the two bricks below it. It would then look more like a real wall and would also make the game more challenging, as the player would have to knock out the "half" bricks at the edges of the stage. I want it to look something like this:



Wall with alternate rows offset

This challenge has two main problems to solve:

1. how to "offset" a row of bricks from the previous row
2. how to apply the offset to alternate rows

I think the second problem is harder than the first so I've provided some hints below, beginning with a subtle hint and ending with a more directly helpful one. Expand each hint (by clicking or tapping on it) in turn until you feel confident to try coding your solution to the challenge. If you get stuck, I've provided my solution below.

Hint 1: odd or even

One way to tell if a number is odd or even is to use the `mod` operator. `mod` (which is short for *modulo* [https://en.wikipedia.org/wiki/Modulo_operation] by the way) means "divide and give me the remainder".

For example, `7 mod 2` means "divide 7 by 2 and give me the remainder": 7 ÷ 2 is 3 remainder 1, so `7 mod 2` is 1. For `2 mod 2`, 2 ÷ 2 is 1 remainder 0, so `2 mod 2` equals 0.

Look at the following sequence and see if you can spot the pattern:

- `0 mod 2 is 0`
- `1 mod 2 is 1`
- `2 mod 2 is 0`
- `3 mod 2 is 1`
- `4 mod 2 is 0`
- `5 mod 2 is 1`
- …

I'm sure you spotted that *even number* mod 2 = 0 and *odd number* mod 2 = 1.

Hint 2: alternate rows

Our code knows how many complete rows we have built so far, and which row we are currently building. If we want to offset every alternate row, we could check if the row we're building is odd-numbered or even-numbered and only offset the odd-numbered rows.

Hint 3: which row are we building?

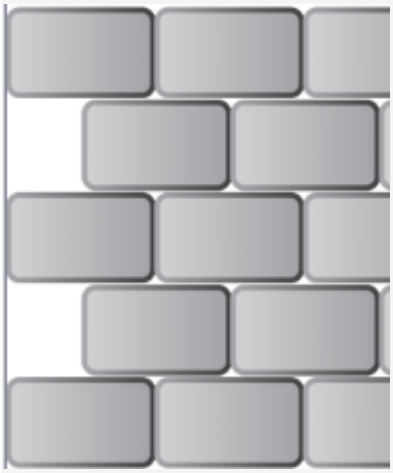
We already have a counter `wall.row` which counts the number of complete rows we've built so far. Before we start building, `wall.row` is zero; after the first row of bricks is laid, we increase `wall.row` to 1. It stays at 1 while we are building the second row; after the second row is complete we increase it to 2. And so on.

We can use this counter to work out if we're about to start an odd-numbered or even-numbered row and act accordingly.

Task

See my first attempt:

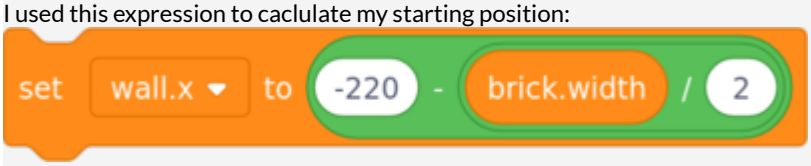
My first try was to start building odd-numbered rows half a brick's width to the right of the usual place. But that left a hole in the left side of the wall which was not what I wanted:



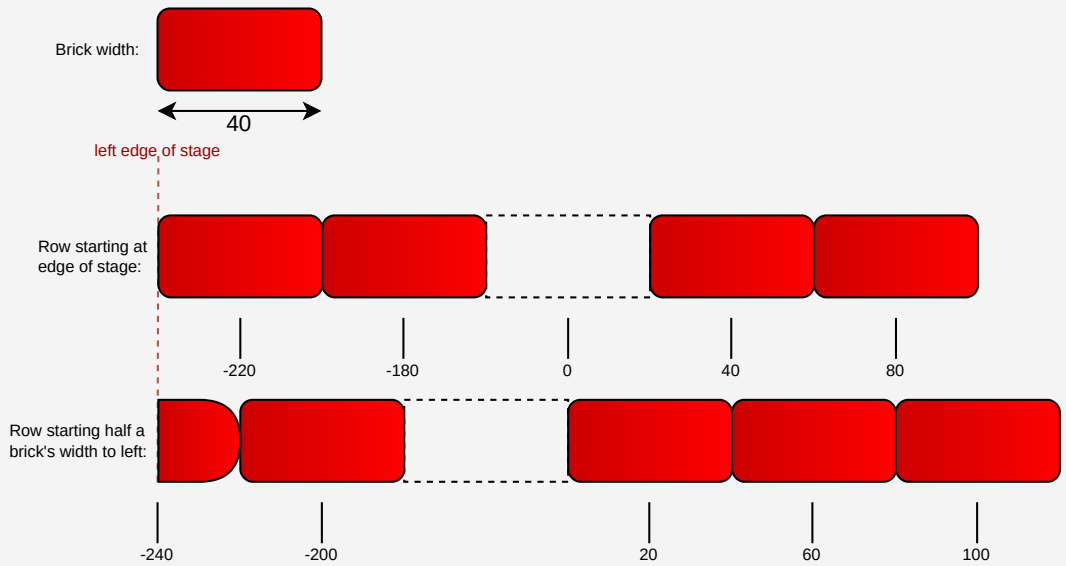
I had introduced a bug (see page 72) in my code and I needed to fix it.

See my second attempt:

For my second try, I started odd-numbered rows half a brick's width to the left of the usual position. So instead of starting at *x* position −220, I started at *x* = −220 − 20 (because 20 is half the width of our brick sprite). In Scratch code, I used this expression to caclulate my starting position:



Note that this means my starting brick will have its centre at the left edge of the stage. Scratch is actually quite happy with this: the brick will be placed but only the right half of it will be visible, which is exactly what I want.

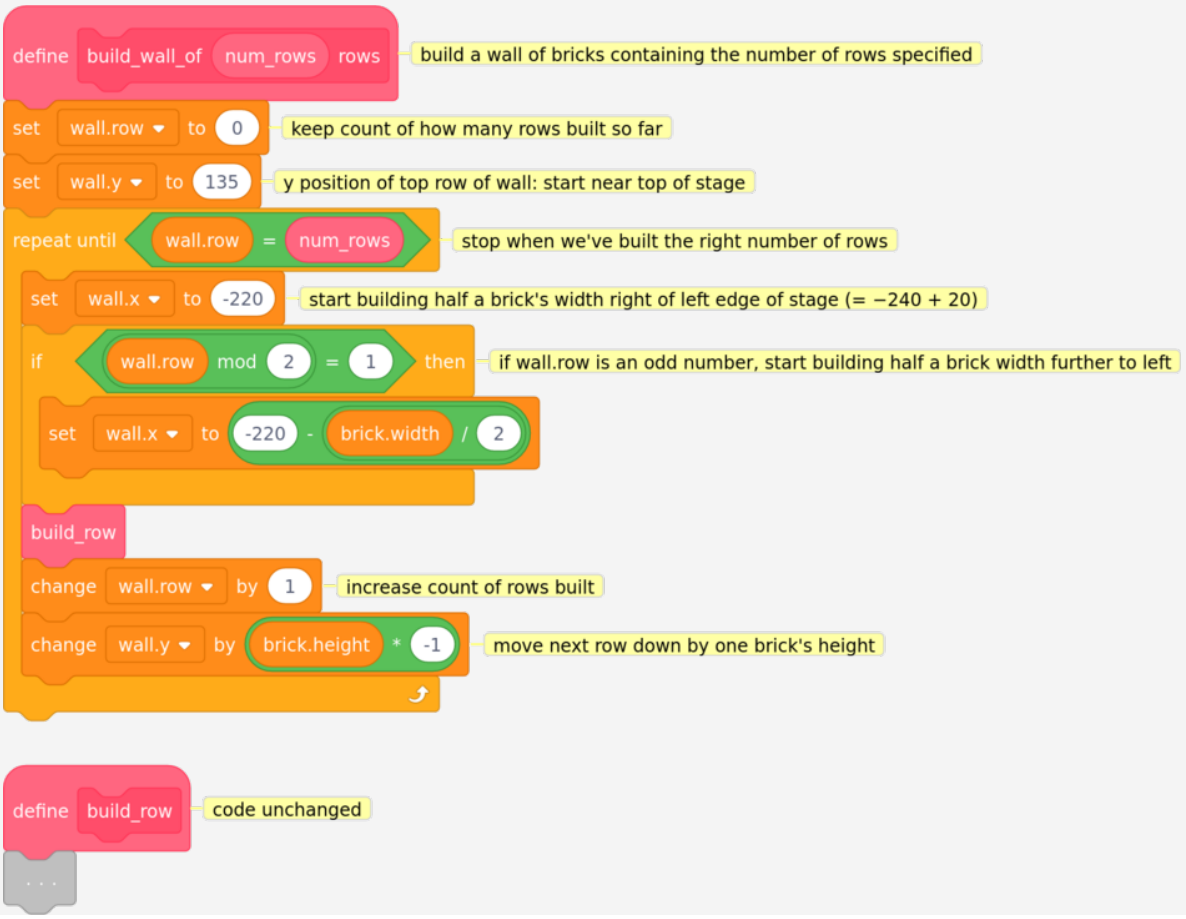


Calculating starting *x* position of staggered rows

The first row of bricks starts at the left edge of the stage (`x=-220`). The second row starts half a brick's width to the left of the edge:

- half a brick's width = half of 40 = 20
- so we start the first brick at *x* position −240 (which is −220 minus 20)
- only the right half of the brick is on the visible stage: the left half of the brick is off the stage and can't be seen.

See my code:



5.3. Give the player three balls (lives)

Let's give the player a better chance of knocking down the whole wall by giving them three balls (or "lives") to start with. When the first ball falls into the water, it's lost and the player will then have two balls remaining, and so on. The game is lost when the player loses their last ball in the water.

This challenge has two parts:

1. Keep track of how many balls the player has left and act accordingly.
2. Inform the player of how many balls they have left.

5.3.1. Keep count of how many balls are left

Task

Add some code to keep track of how many balls the player has left and only end the game when the last ball is lost. For now, don't worry about how to inform the player — we'll look at that in the next section.

I have provided some hints if you need them. Click or tap on each hint in turn until you feel confident enough to write your code.

Hint 1:

Make use of the existing messages/events we have already defined. Use them as "hooks" to hang your extra code onto.

Hint 2:

Use a variable (see page 73) to keep count of the number of balls the player has left. I named it `game.balls_left` because it belongs to the game as a whole rather than an individual sprite. It will need to be available to all sprites.

Hint 3:

Recall that there is a message (event) `game.setup` which is broadcast when the game's setup code is run. This is an ideal place to set the starting value of your variable.

Hint 4:

The event `ball.hit_water` used to signify that the game was lost. As the player now has more than one ball, change the "player has lost the game" code's 

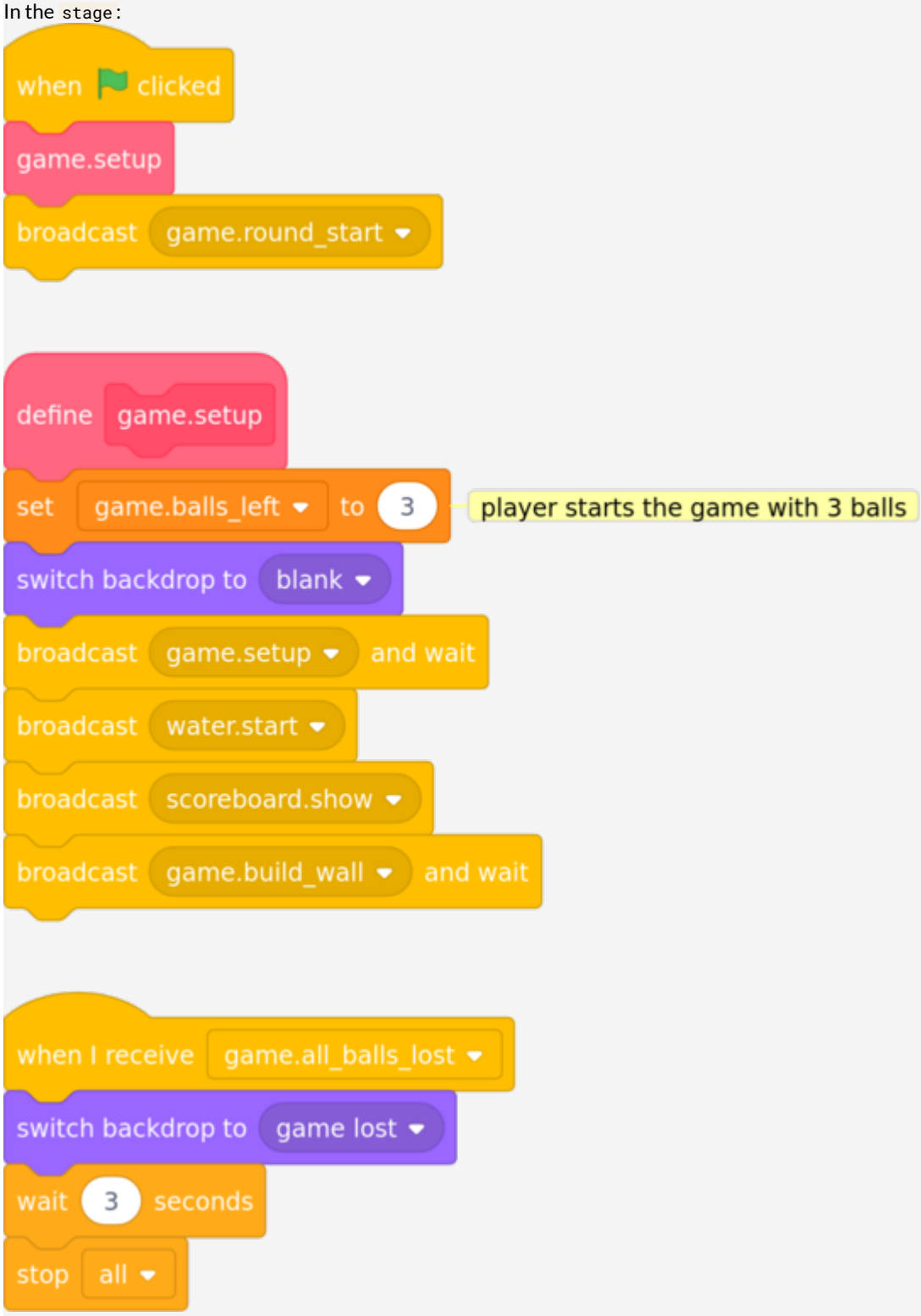
hat block to respond to a new message (I called it `game.all_balls_lost`).

Hint 5:

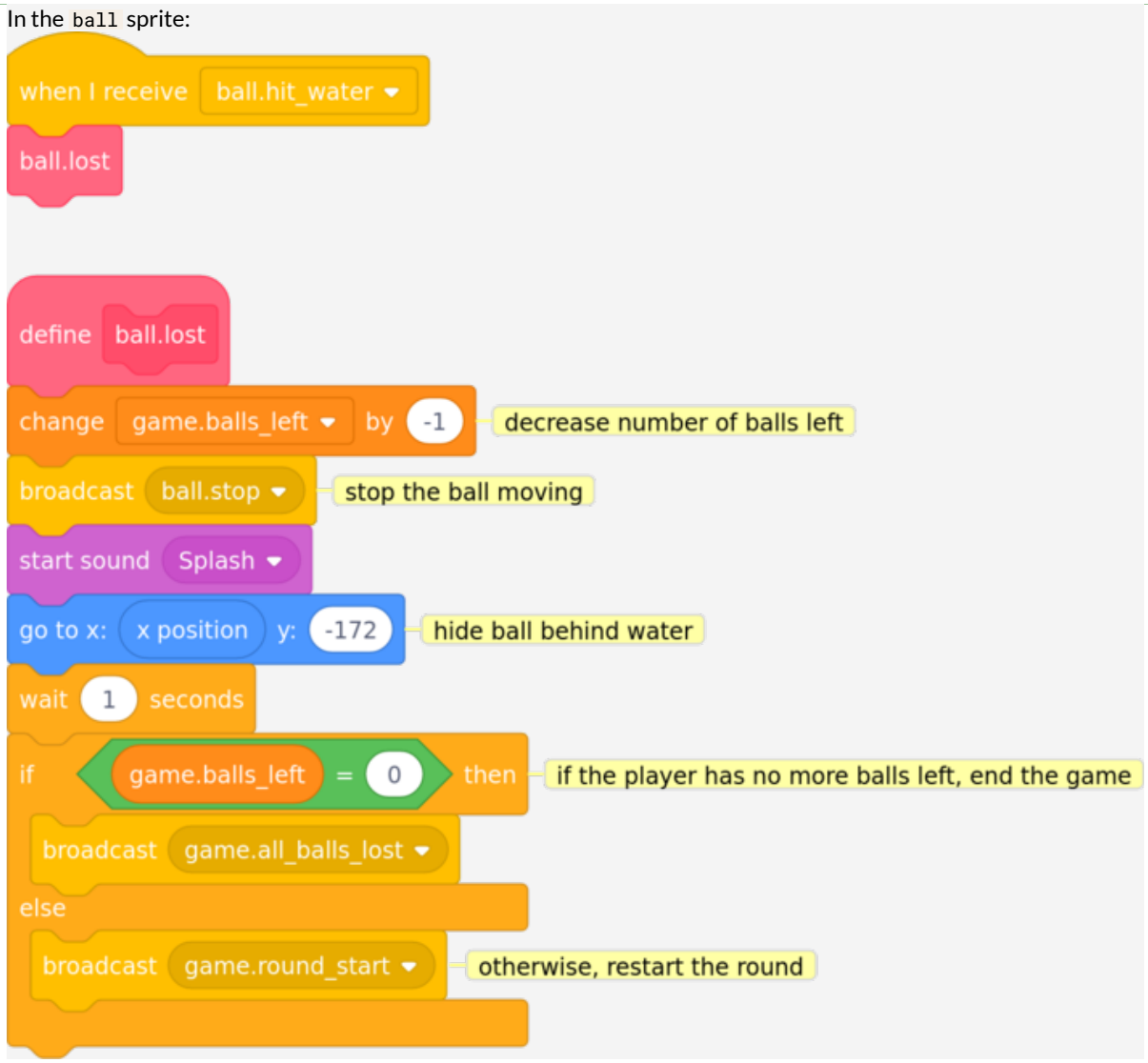
The `ball.hit_water` message is broadcast when a ball falls into the water. What do we need to do with our "how many balls are left" counter when this happens? What if the lost ball that was the player's last ball?

See my code:

In the `stage`:



In the `ball` sprite:



When testing your code, remember that you can display variables on the stage by ticking the box to the left of them in the 

category. This will allow you to watch your "count of balls remaining" variable as your code runs.

5.3.2. Inform the player how many balls are left

Task

We now need to find a way to display how many balls the player has left. Scratch is quite limited in how you can relay information back to the user. We can

- use a 

or 

block to get a sprite to display a short string of text.
- display the value of a variable (as a number or text); Scratch has three different styles of display: right-click or long press on the displayed variable to change its display style. Scratch calls the display of a variable on the stage a stage monitor [https://en.scratch-wiki.info/wiki/Stage_Monitor] . (The slider style is useful for allowing the player to adjust the speed of the ball.)

The simplest solution I could think of was to name my counter variable as I wanted it to be displayed (e.g. `balls left`), drag it to the corner of the stage and leave it there all the time. That has the advantage of being very easy to implement: I wouldn't even have to write any code. The disadvantage is that it would be hard to extend it to display more information later on.

I found it quite tricky to come up with a better way to inform the player how many balls they have left. I had in mind some kind of scoreboard display which could be extended later to show more information such as number of balls left, ball speed, score etc. There isn't room for it on the stage, so I decided that the scoreboard should only be shown when the ball is not moving, during the breaks in play.

This idea has the advantage of flexibility: it can be extended later to show more information. But the downside is that it's a bit more complex: the more complex it is to implement, the more likely we are to introduce bugs (see page 72). After weighing up the pros and cons, I decided the the extra flexibility was worth the slightly more complex code.

You may well have a better idea of how it could be done. If so, go ahead and try to code it. If you need some ideas, take a look at my design below.

See my design:

My solution (which is by no means the only way, and may well not be the best way) was to make a sprite that looks something like a scoreboard. The scoreboard could display game information such as how many balls are left and also use the say block to give the player short messages or instructions. The actual message shown will be controlled by another variable named `scoreboard.message`.

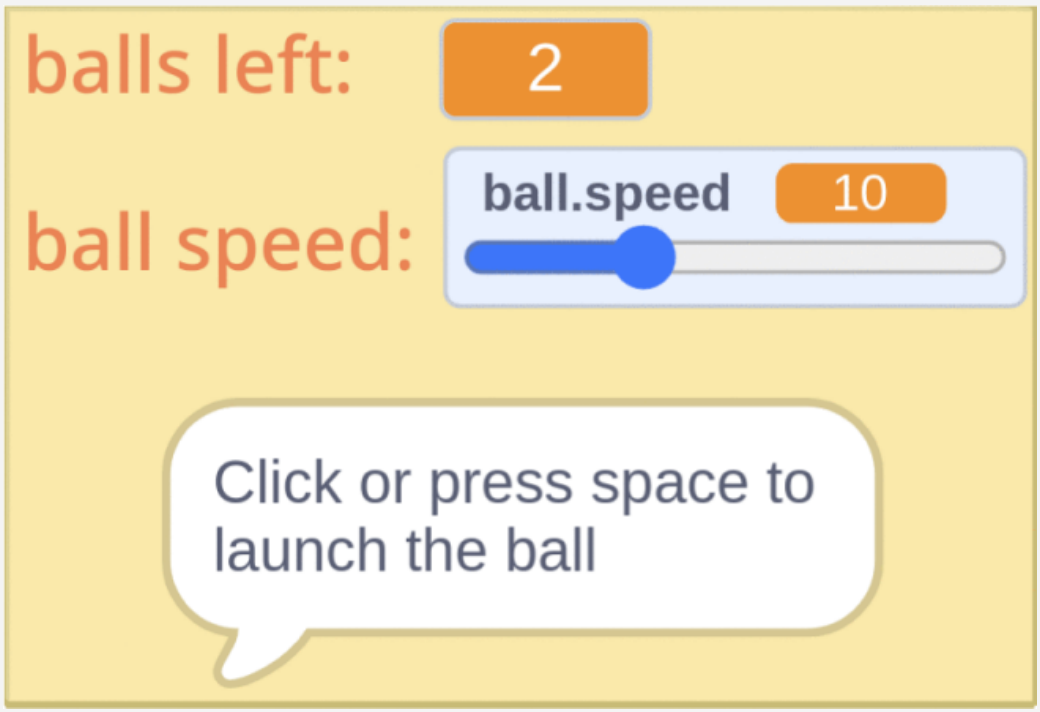
In order to have fine control over the positioning of the speech bubble when the sprite "talks", I added a second sprite (its costume is a single black pixel (see page 73)) which I made invisible by setting its ghost effect [https://en.scratch-wiki.info/wiki/Graphic%20Effect#Ghost_3] to `100` in code. This sprite is what does the talking: it contains the 

instructions. By moving this `scoreboard_message` sprite around, I can position the speech bubble anywhere on the stage.

I added static text to the scoreboard's costume so that it contains the headings that won't change. I then set the variables I wanted to display to visible (by ticking them in the 

category) and dragged them to the right place on the scoreboard.

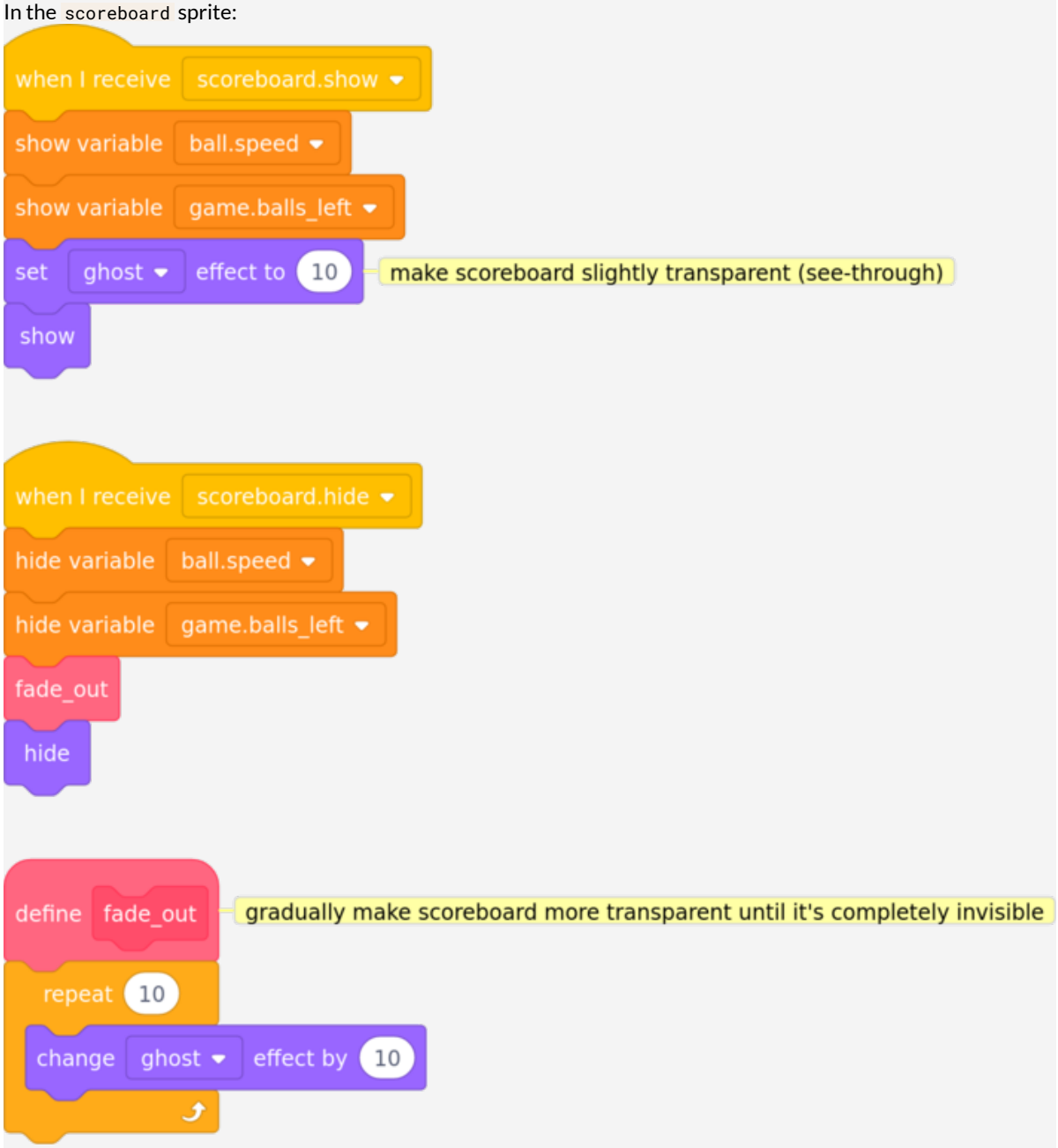
Because we can show or hide variables in code, I can completely hide the whole scoreboard while the ball is in play. All I need to do is to make all the elements of the scoreboard (the `scoreboard` sprite, the `scoreboard_message` sprite and the displayed variables) respond to *show* and *hide* messages. I named the messages `scoreboard.show` and `scoreboard.hide`.



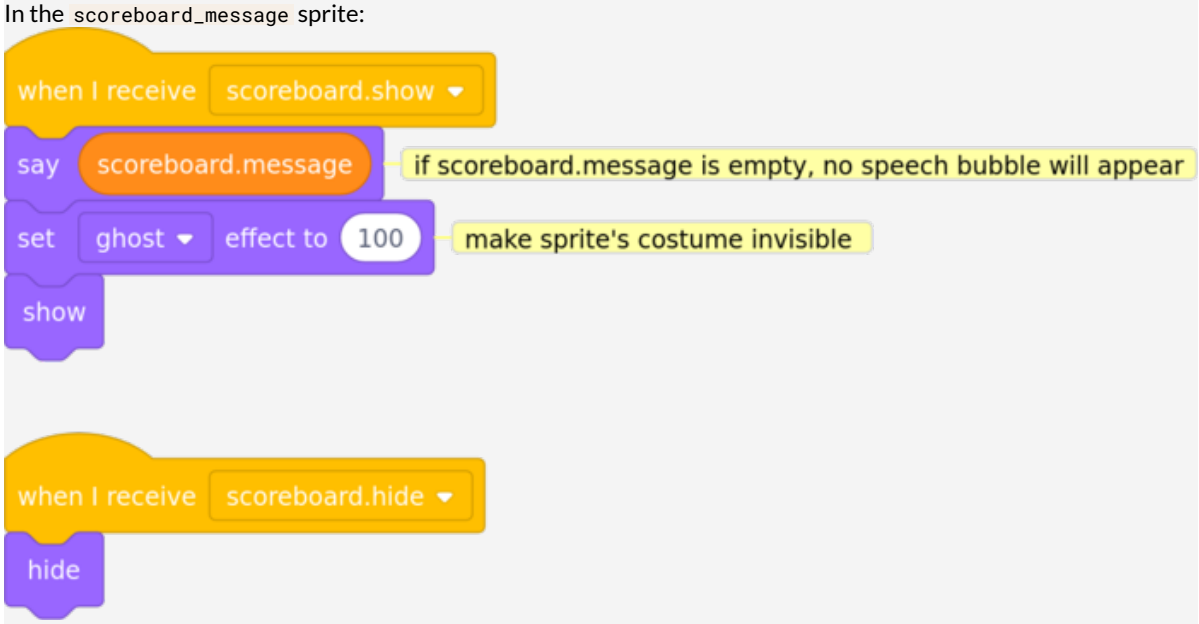
Scoreboard showing balls left, ball speed & a message to the player

See my code:

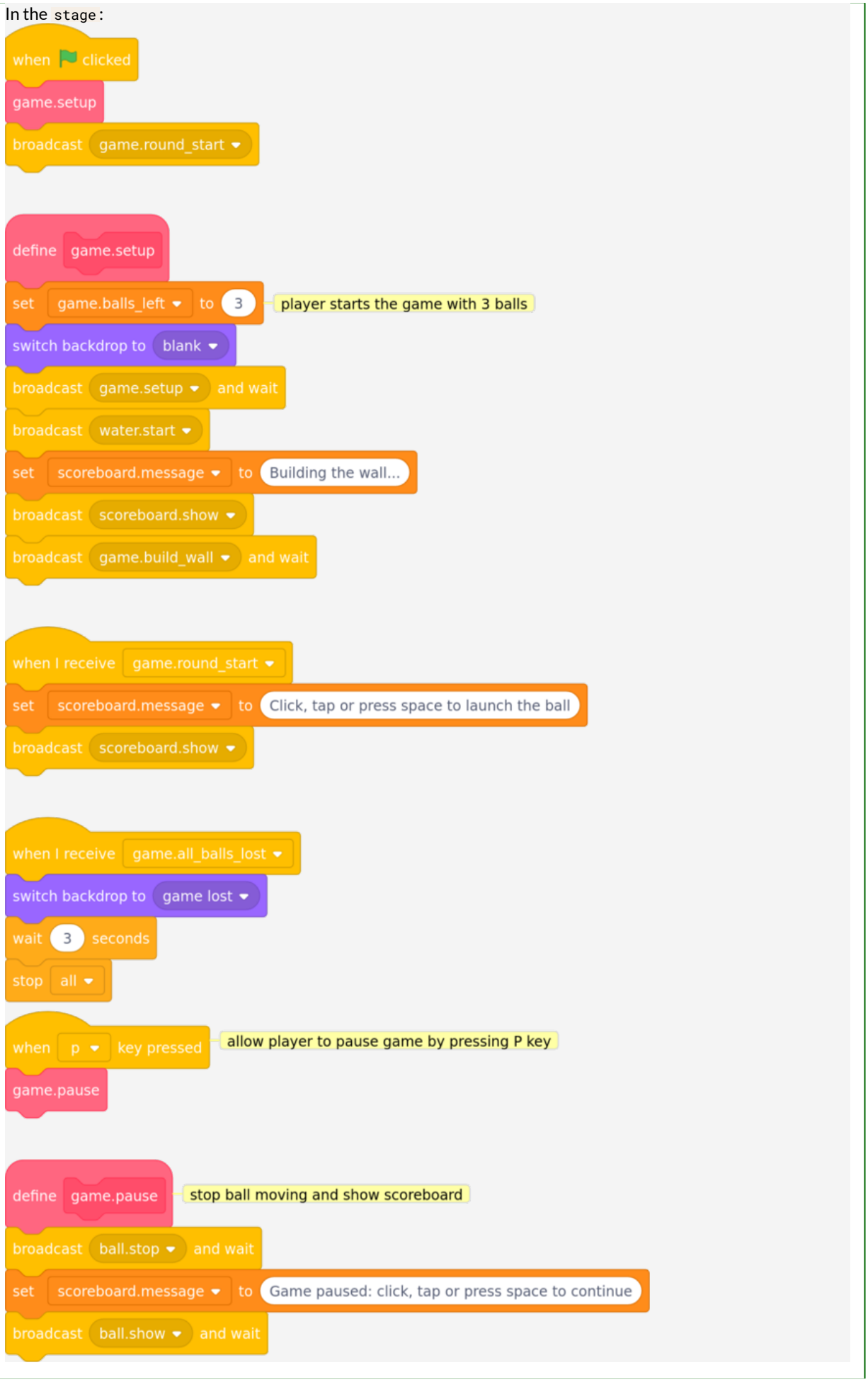
In the `scoreboard` sprite:



In the `scoreboard_message` sprite:



In the `stage`:


when clicked
game.setup
broadcast game.round_start
define game.setup
set game.balls_left to 3
player starts the game with 3 balls
switch backdrop to blank
broadcast game.setup and wait
broadcast water.start
set scoreboard.message to Building the wall...
broadcast scoreboard.show
broadcast game.build_wall and wait
when I receive game.round_start
set scoreboard.message to Click, tap or press space to launch the ball
broadcast scoreboard.show
when I receive game.all_balls_lost
switch backdrop to game lost
wait 3 seconds
stop all
when p key pressed
allow player to pause game by pressing P key
game.pause
define game.pause
stop ball moving and show scoreboard
broadcast ball.stop and wait
set scoreboard.message to Game paused: click, tap or press space to continue
broadcast ball.show and wait

As always, test your code to check that it does what you intend it to do.

5.4. Give the game more than one round

As it stands the game is short and relatively easy to complete. To make our game more interesting and challenging for the player, let's introduce several rounds of play: once the player has demolished the whole wall, the game should display a *"well done"* message and then move on to the next round. As the player progresses through the rounds, the game should become progressively more challenging.

5.4.1. Design

The first question is: how does moving on to the next round affect the gameplay? Well, we want each round to be more difficult than the last so I suggest that for each round:

1. the wall should become larger
2. the speed of the ball should increase.

Thanks to the flexible way we've coded our game so far, these should be easy to achieve in code: the `wall` sprite already has a `build_wall_of (num_rows) rows` block, so we just need to tell it how many rows of bricks to build for each round. Likewise, the speed of the ball is controlled by the `ball.speed` variable, so we just need to increase this value for each round.

The next design decision is how easy or difficult to make the game. If we want our game to appeal to the widest number of players, we need to accommodate a range of skill levels. Therefore I suggest we also introduce a *difficulty* setting to our game: we allow the player to choose between *easy*, *medium* or *hard*. The player's choice will determine the game's starting level of difficulty.

For the wall, I suggest that on the *easy* difficulty level we opt for the easiest possible game in round 1: start with just one row of bricks and the ball moving slowly. Then for each subsequent round we add one more row of bricks to the wall and (gently) increase the speed of the ball. On *medium* and *hard* difficulty settings we could start round 1 with more rows of bricks in the wall and a slightly faster ball speed.

After some trial and error testing and asking a few people to play the game while adjusting the settings, I ended up with this design:

	Round 1	**Each subsequent round**
Easy	1 row of bricks ball speed: 5	1 additional row of bricks ball speed: increase by 2
Medium	1 row of bricks ball speed: 10	1 additional row of bricks ball speed: increase by 2
Hard	1 row of bricks ball speed: 15	1 additional row of bricks ball speed: increase by 2

So on *easy* difficulty:

- round 1: 1 row of bricks, ball speed: 5
- round 2: 2 rows of bricks, ball speed: 7
- round 3: 3 rows of bricks, ball speed: 9
- …

On *medium* difficulty:

- round 1: 1 row of bricks, ball speed: 10
- round 2: 2 rows of bricks, ball speed: 12
- round 3: 3 rows of bricks, ball speed: 14
- …

On *hard* difficulty:

- round 1: 1 row of bricks, ball speed: 15
- round 2: 2 rows of bricks, ball speed: 17
- round 3: 3 rows of bricks, ball speed: 19
- …

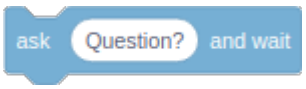
I initially decided that on *hard* difficulty the wall would start with 2 rows of bricks, but that creates a problem: what if the player pauses the game mid-round and changes the difficulty setting? It would be difficult to insert another row of bricks into a partly demolished wall half-way through a round. I decided to side-step this complication and keep it simple: start with one row of bricks and add one more per round.

The ball speed values that I have chosen can be calculated via a single formula. If we assume that the difficulty level is assigned to a variable (I called it `game.difficulty`) where *easy* has the value `1`, *medium* is `2` and *hard* is `3`, then we can say:

```
set ball.speed to (game.difficulty * 5)  +  ( (round - 1)  * 2)
```

5.4.2. Allow the user to set the level of difficulty

I have already decided to represent the difficulty level in my program as a number from 1 (*easy*) to 3 (*hard*). But how should we get this information from the player?

One solution could be to use an 

block: that would be simple and easy to implement. We would need to check the player's answer to ensure that it is one of our allowed values (in coding we call this validation (see page 73)), but this would not be too hard to achieve. The solution could look something like:

```
repeat until we get a valid response:
    ask [What level of difficulty (1 for easy, 2 for medium, 3 for hard)?]
    set difficulty to (answer)
end repeat
```

However I decided to not to use an `ask` block but instead use *radio buttons*: a set of buttons of which only one can be selected at once (they are sometimes known as option buttons).

One advantage is that radio buttons are familiar to most computer, tablet and smartphone users. You will almost certainly have seen options like this on web pages:

> Select difficulty level: easy medium hard

Another advantage of radio buttons is that we don't need to validate the input as the user can only select from the options we have provided. The main disadvantage is that they are not built in to Scratch, so we will have to implement them ourselves.

In this case I decided the extra complexity was worth the trouble to achieve a more polished user interface. I also think it's a useful demonstration of a component that you can re-use in your own Scratch programs (see the standalone radio button component projects [https://scratch.mit.edu/studios/27091806/] if you want to do this).

5.4.2.1. The `buttonSet.difficulty` sprite

This section details the design of the 'radio button set' sprite. I'm not necessarily expecting you to be able code this yourself, but I wanted to explain its design and how it works. Please don't worry if you don't understand it immediately as it's not crucial to building the game.

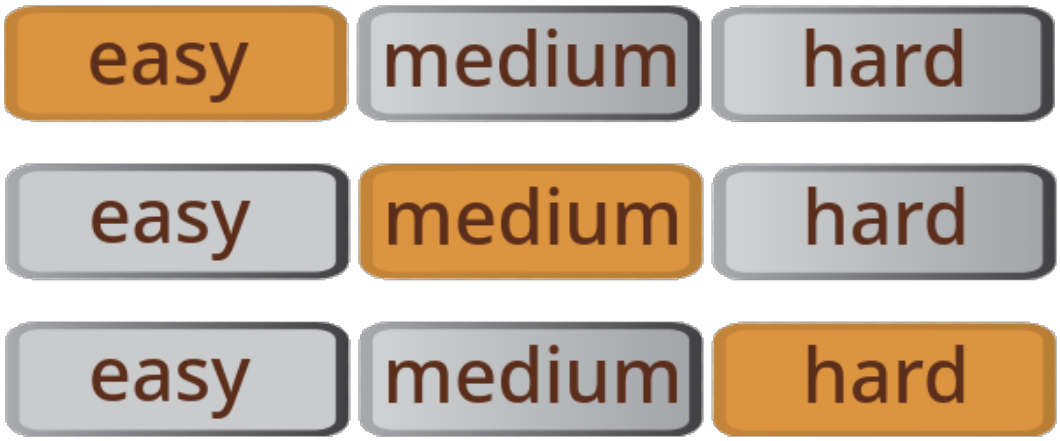
I created a sprite which shows all the buttons in the set: in this case one button labelled *easy*, one labelled *medium* and one labelled *hard*. The sprite has one costume for each possible selection: one costume showing *easy* selected, one showing *medium* selected and one showing *hard* selected.

I will use the *x* position of the mouse pointer at the time the user clicks the sprite to work out where on the sprite the user has pressed. If I know how wide the buttons are, I can then work out which button in the set the user has clicked on.

I made all the buttons the same width and spaced them equally in order to make the calculation as simple as possible. For my set of three buttons I divide the width of the sprite into three equal thirds:

- if the user clicks on the left third, he/she has selected *easy*
- if the user clicks on the central third, he/she has selected *medium*
- if the user clicks on the right third, he/she has selected *hard*

The image below shows the sprite's three different costumes:



The `buttonSet.difficulty` sprite's costumes

I use internal variables to store the width of each button (`button_width`) and the width of the whole set of buttons (`buttonSet_width`). Before I use the sprite for the first time, I call its `setup` block to set these values. (I actually scale these widths in proportion to the sprite's `size` value: that way, I can resize the sprite without having to change my calculations of where the user clicked.)

I also use an internal variable named `selected` to keep track of which option is selected: `1` for the first option, `2` for the second, and so on.

To indicate to the user which option is selected, we simply change the sprite's costume: the first costume for option 1 (*easy*), the second costume for option 2 (*medium*) and so on.

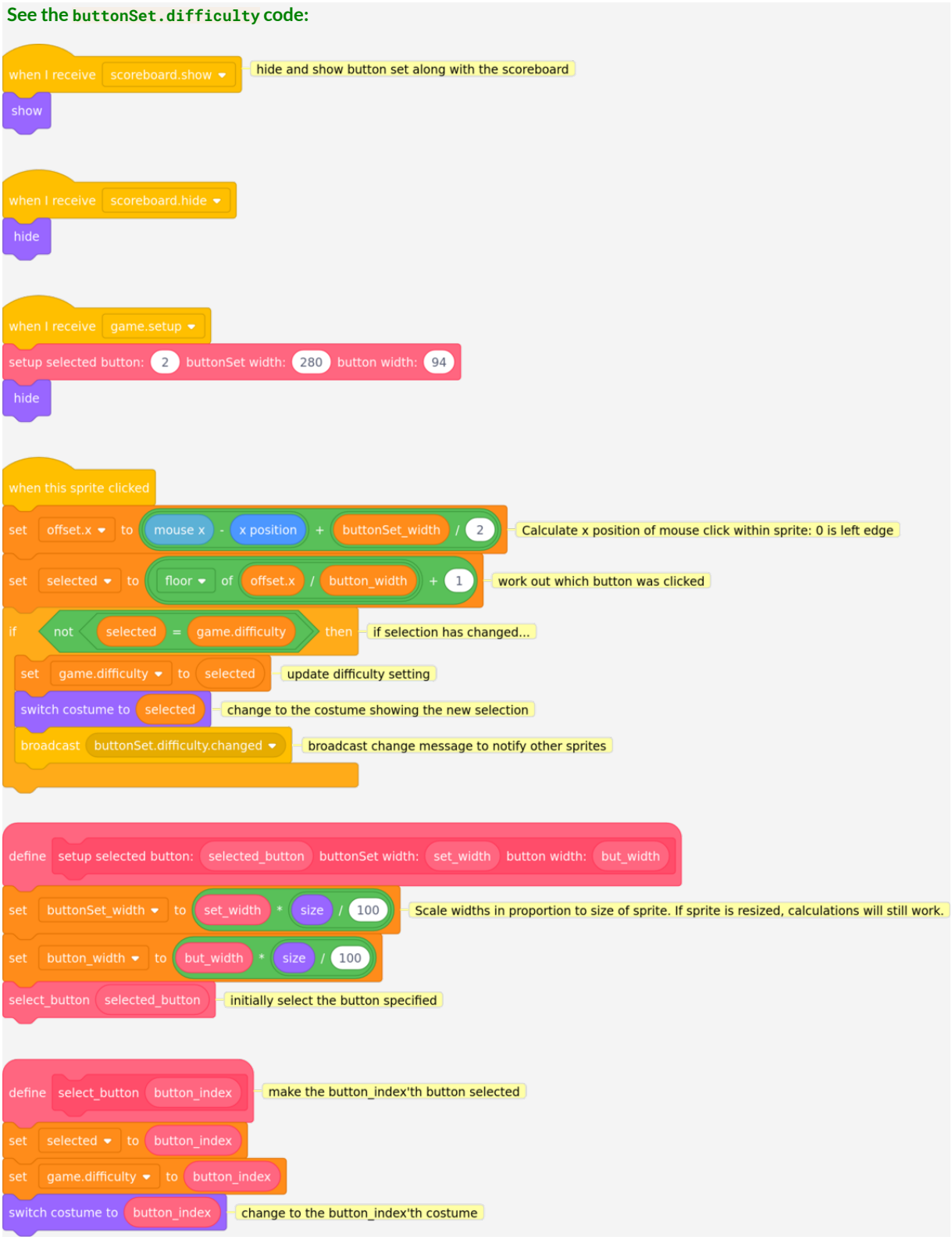
Once the button set has been initialised by calling the `setup` block, the flow of the code is fairly straightforward.

When the sprite is clicked:

1. Work out the *x* position of the click within the sprite (use `0` to mean the left edge of the sprite)
2. Divide this position by the width of one button (ignore anything after the decimal point – just take the whole number).
   For our set of 3 buttons, this will give us a result of `0`, `1` or `2` meaning the left, centre or right button was clicked respectively.
   Add `1` to this value to obtain the number of the option that was selected.
3. If the selected button has changed:
    1. Change the variable `game.difficulty` so that the other sprites know which option is selected
    2. Change the costume to show the new selection
    3. Broadcast a message so the other sprites know that the user changed the selected option

I have included the code here for you to refer to, but it is available in the extra sprites for Demolition Challenges project [https://scratch.mit.edu/projects/409927568/] so feel free to copy the whole sprite including its code into your project via the backpack at the bottom of the Scratch screen.

See the `buttonSet.difficulty` code:



I tested my code by making the sprite's internal variables and the `game.difficulty` variable visible on the stage by ticking the box to the left of them in the Variables category, then clicking at various locations on the sprite and checking that the correct option was selected. I also tested that clicking outside the sprite did not change the selection.

5.4.3. Implementation

Task

In addition to the `game.difficulty` variable, we also need to create a couple of other new variables (accessible to all sprites):

- `game.round` to record which round is currently being played
- `game.last_round` to indicate the last round of the game: if player completes this round, they have completed the game

Create the variables and set their initial values (the obvious place to initialise them is in our `game.setup` block).

Next, we need some code to move the game on to the next round once the player has demolished the wall: I called this block `game.next_round`. We'll need to move some code from `game.setup` into this block, as some of the steps need to happen before every round.

Try to write the code for the `game.setup` block. If you get stuck, have a look at the hint below or read through my code below and try to follow what it's doing.

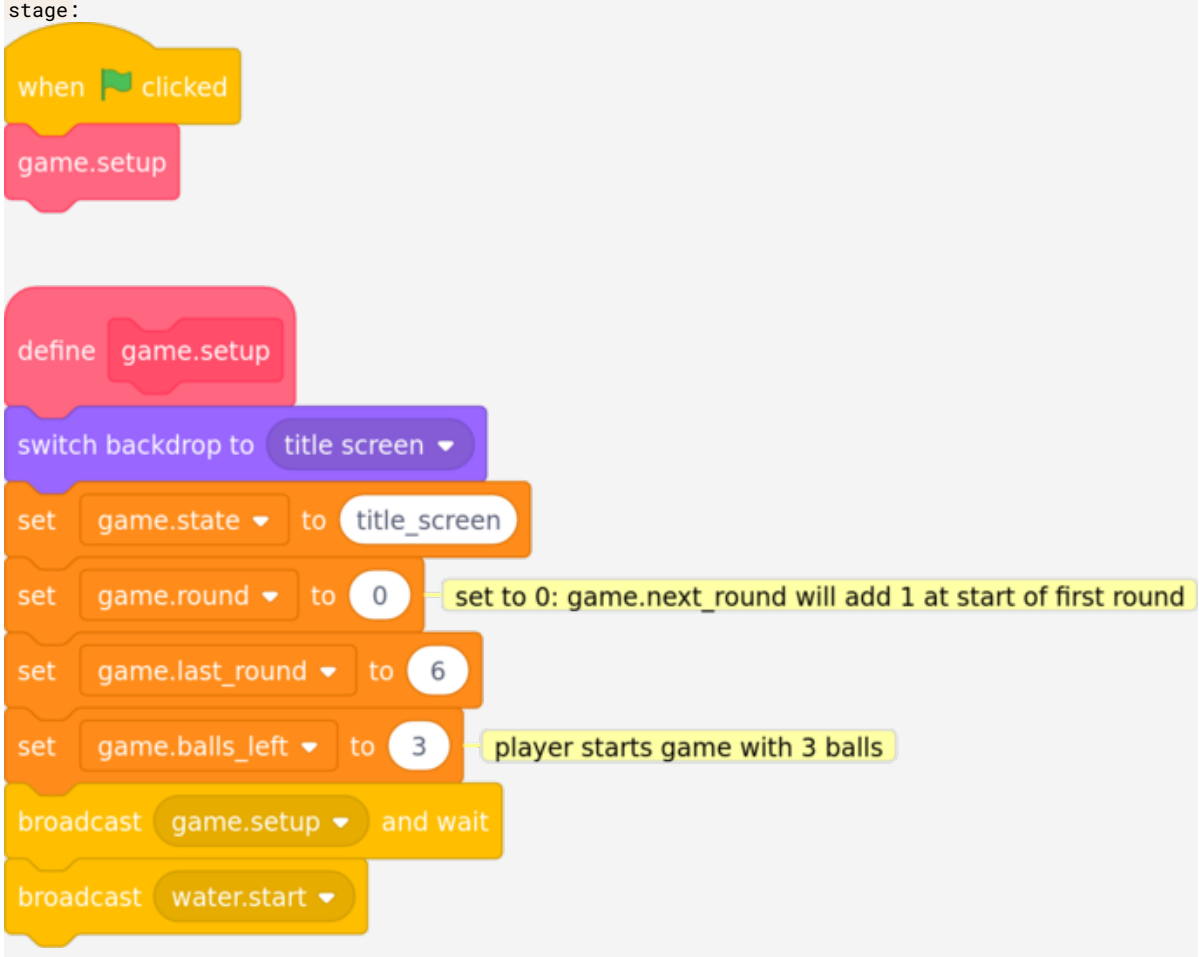
Hint:

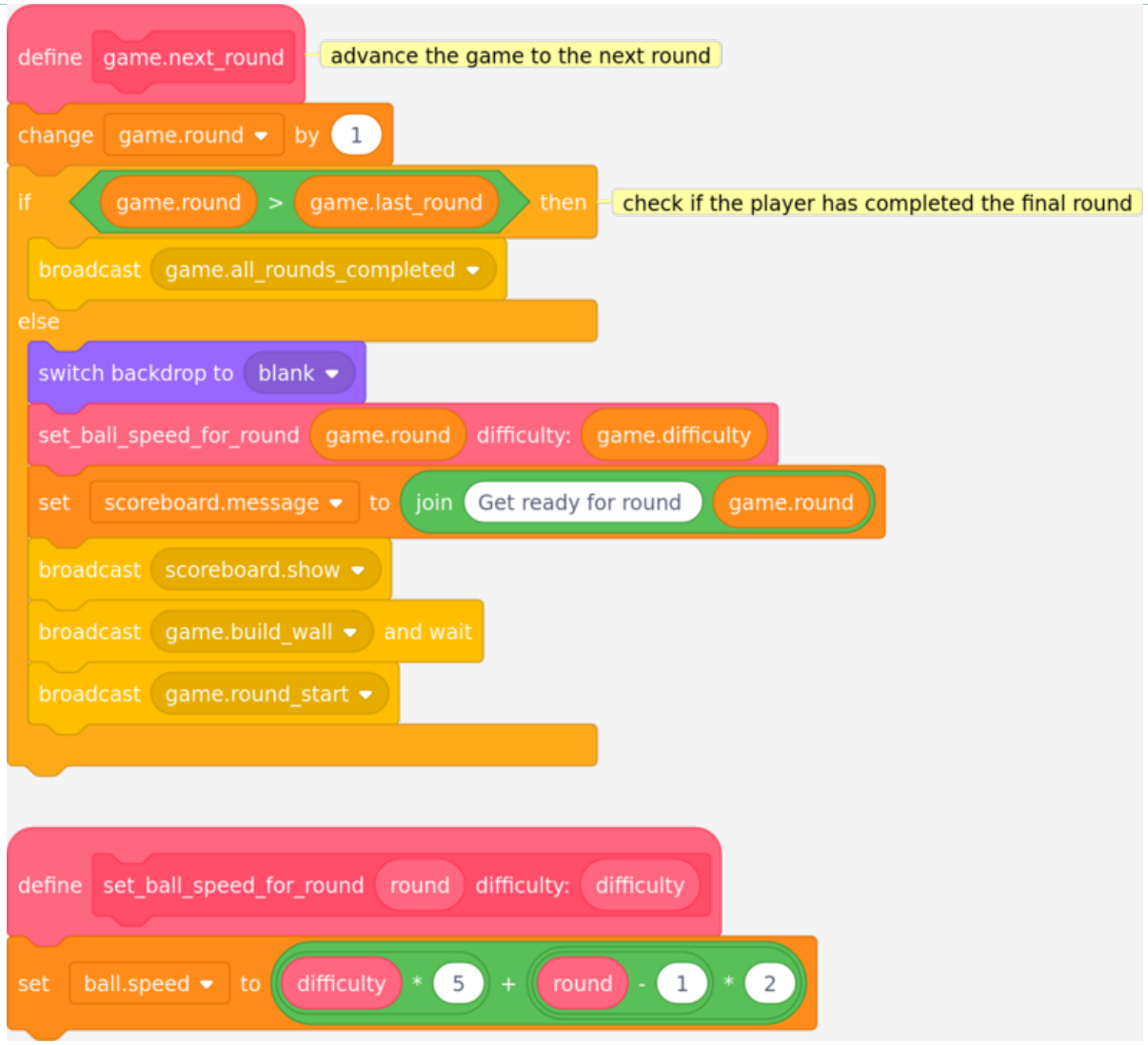
We also need to add the following steps to `game.next_round`:

- Increase the `game.round` counter and check if the player has completed the whole game
  - if so, broadcast a message: I called it `game.all_rounds_completed`
  - if not, while the wall is building, let the player know (via a message on the scoreboard) which round is about to start
- Set the value of `ball.speed` using the formula we wrote above

See my code:

`stage`:



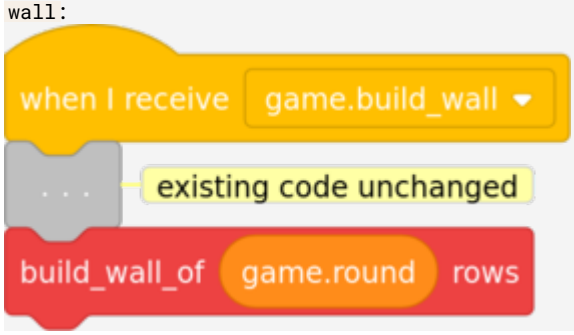


Because we are not yet calling this block anywhere in our code, I tested it by dragging the `game.next_round` block to an empty part of the stage's code (on its own, not attached to any other code) and clicking it to run the block. Check that `game.round` is increased when the block is run and that the code correctly recognises when it moves past the final round.

Next we need to adjust the `wall` code to build the right number of rows of bricks for the upcoming round. As I decided to have the same number of rows of bricks as the number of the round, this is very simple. Adjust your code and, as always, test that it works.

See my code:

`wall:`



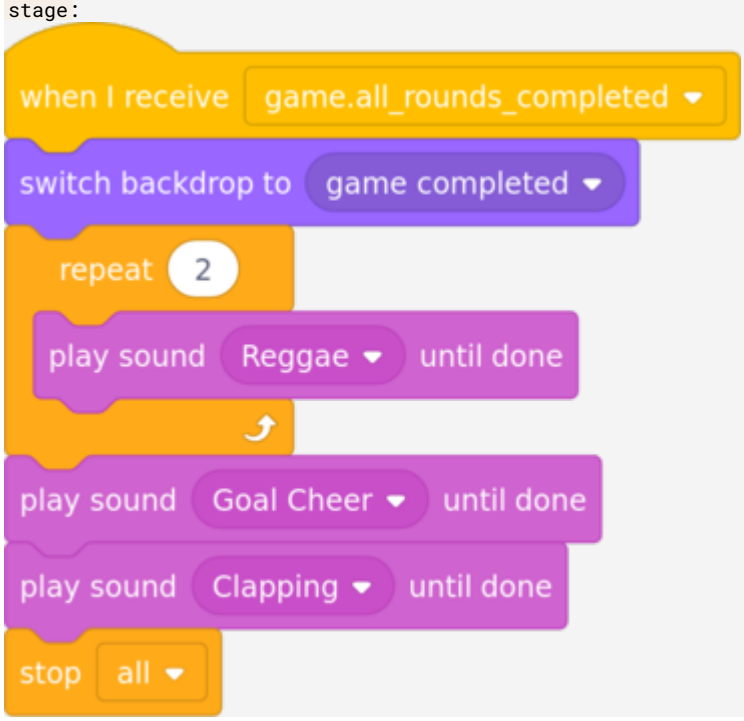
It's just as simple to test this code: set `game.round` to each number in turn, run the `game.next_round` block and check that the wall has the number of rows you expect (one row in round 1, two rows in round 2 etc).

Now that we have defined the `game.all_rounds_completed` message which is broadcast when the player completes the game, now is a good time to write that code. As a minimum, we should probably show a messaage congratulating the player on their magnificent achievement, but how you design this part of the game is entirely up to you — make it as imaginative (or as simple) as you like. You could design a spectacular backdrop, play a tune, show an animation of a fireworks display…

Anyway, here's my version which uses a new background named `game completed` (available in the extra sprites for Demolition Challenges project [https://scratch.mit.edu/projects/409927568/]) and some library sounds:

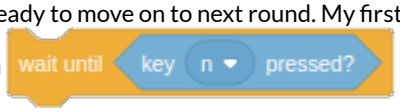
See my code:

`stage`:



To test your code, create a `broadcast game.all_rounds_completed` block (on its own) and click to run it.

Task

We need a way for the player to indicate they are ready to move on to next round. My first design was to ask the player to press the *n* key (*n* for *next round*) and use a 

block. This was simple to implement but it's not really convenient for players using touchscreen devices to have to bring up the on-screen keyboard just to type the single letter *n*.

Ideally we want the player to be able to click (or tap on a touchscreen device) or press a key. If you're thinking that this sounds very similar to how the player currently launches the ball at the start of a round or after a ball was lost in the water, then you're thinking along the same lines as me. Could we re-use that same mechanism (and hopefully the same code) to move to the next round?

The answer is yes, but the code will need to behave slightly differently depending on where the player is in the game:

- at start of a round, launch the ball
- if the game is paused, resume the game
- if the player has just completed a round, move on to the next round

So we need a way to determine what state the game is in to know what to do when the player clicks, taps or presses space. Can you think of a way to do this?

See my solution:

My solution to this is to use a variable named `game.state` to store the state of the game. The variable will have one the following values:

- `title_screen` : indicates the game is at the opening title screen
- `round_start` : indicates the game is at the start of a round
- `in_play` : indicates the ball is in play
- `pause` : indicates the game is paused
- `round_completed` : indicates the player has just completed a round
- `all_rounds_completed` : indicates the player has just completed the whole game
- `all_balls_lost` : indicates the player has lost their last ball

To keep my code tidy I created a block named `game.continue` which decides what happens in response to the player clicking, tapping or pressing space (in the `stage` with all the other code that relates to the game as a whole). Go ahead and create the `game.continue` block and add code to move the game to the appropriate state depending on the value of `game.state`. Then add the code to set the value of `game.state` when a new state is triggered.

Hint 1:
We already use a number of custom blocks to trigger various game states. Look at the existing code in the `stage` to jog your memory.

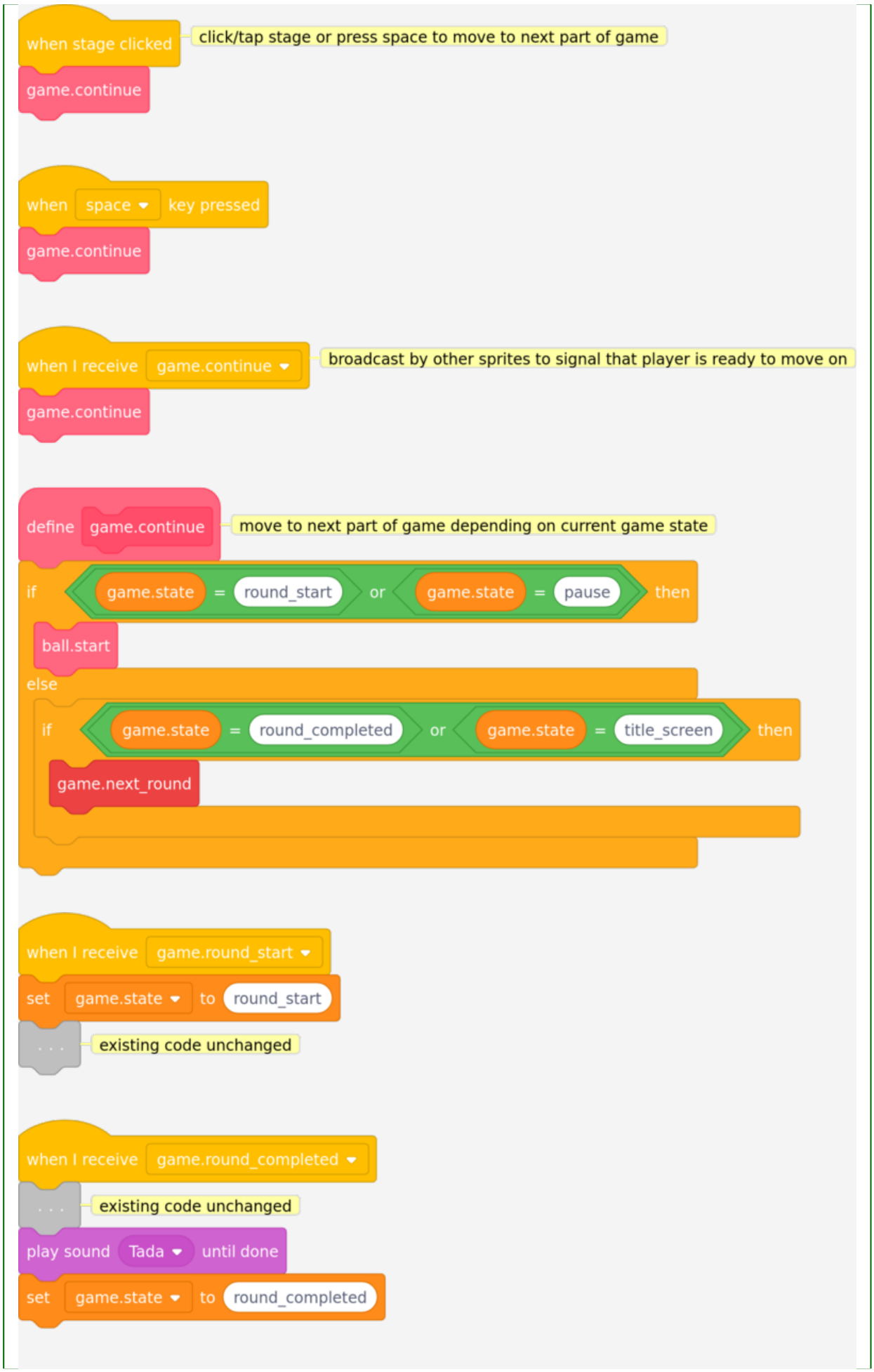
Hint 2:

The logic for this code can be written as follows:

- if `game.state` is `round_start` or `pause` then start the ball moving
- if `game.state` is `title_screen` or `round_completed` then move on to the next round
- otherwise, don't do anything

See my code:

```
stage:
```



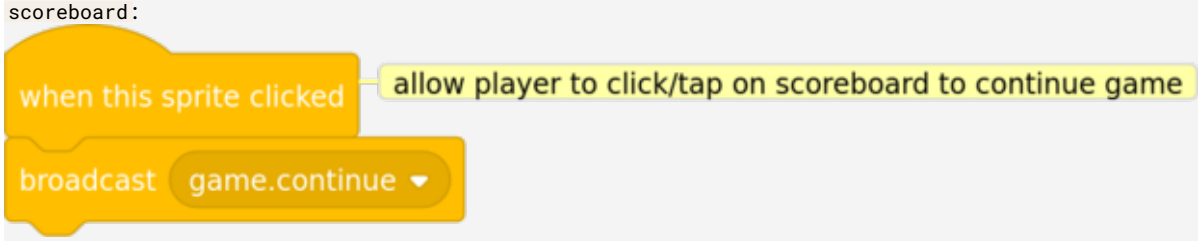
define ball.start

set game.state to in_play

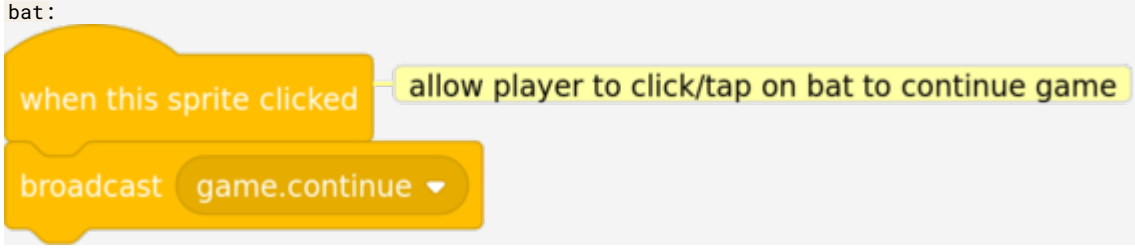
Notice that I am also calling `game.continue` when I receive a message with the same name. This will allow us to capture clicks/taps on other sprites (not just the stage) and have those sprites indicate that the player is ready to move on.

Here's the code to do that:

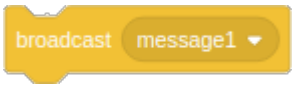
`scoreboard`:



`bat`:



Testing this code can be tricky as it affects many different parts of the game. I made the `game.state` variable visible and started the program, checking that the value was what I expected when the game was in the various different states.

Remember that you can drag in a temporary 

block and click it to simulate gameplay events (such as a round being completed) without having to play the game all the way through.

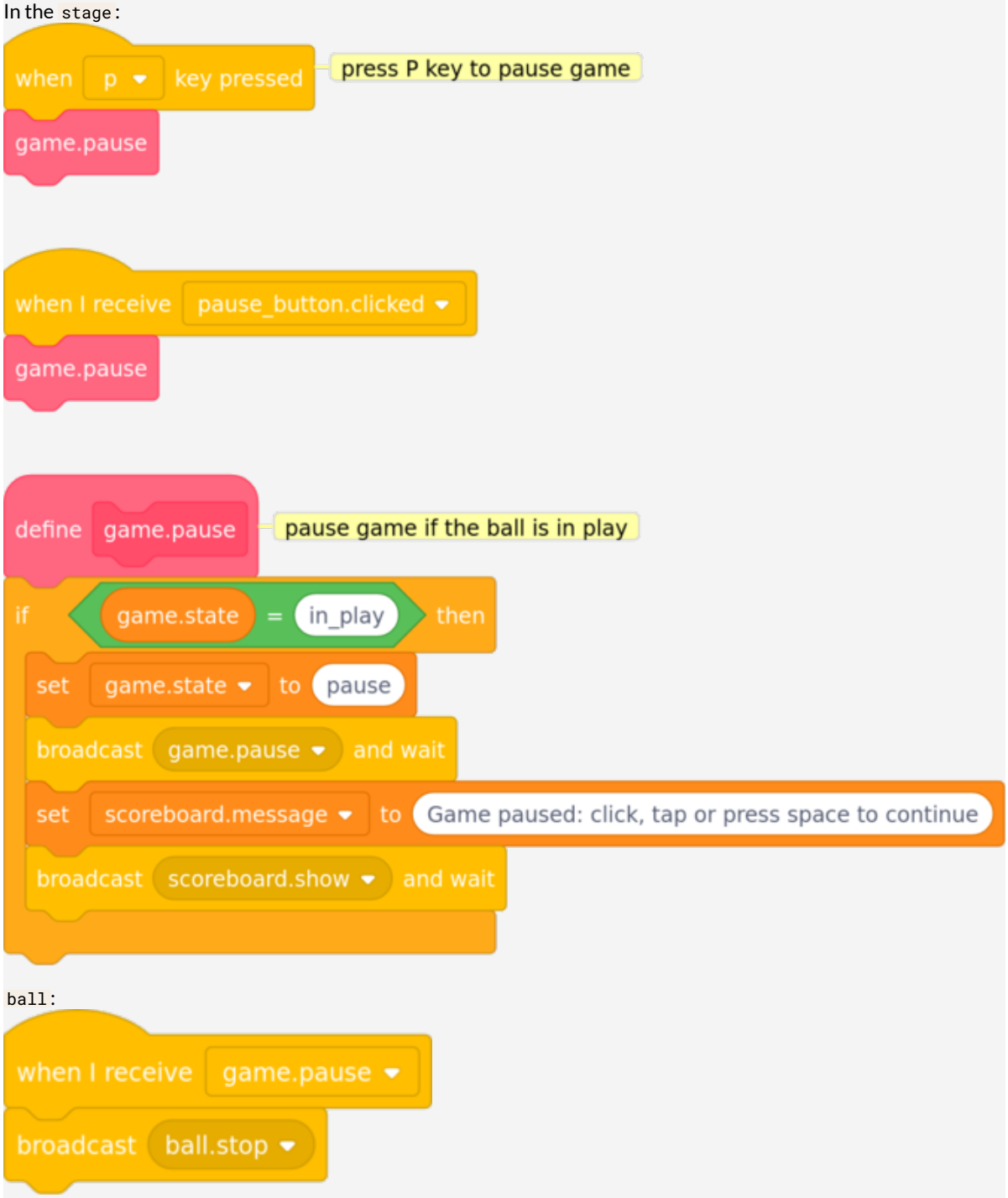
It was while testing this code that I found a bug: it's possible to press *p* to pause the game when the ball is not in play. Doing this got the program into a very confused state as it's not something it was expecting. Can you think of a way to fix the bug?

While I was working on the 'pause the game' feature, it occurred to me that only allowing the player to press *p* is not at all touchscreen-friendly: by the time the player has brought up the on-screen keyboard, the ball will probably have already fallen into the water.

It would be much easier for touchscreen users to be able to tap a pause button somewhere on the screen, so I added a `pause_button` sprite at the bottom right of the stage. The costume for this sprite is available in the extra sprites for Demolition Challenges project [https://scratch.mit.edu/projects/409927568/] .

See my fixed code:

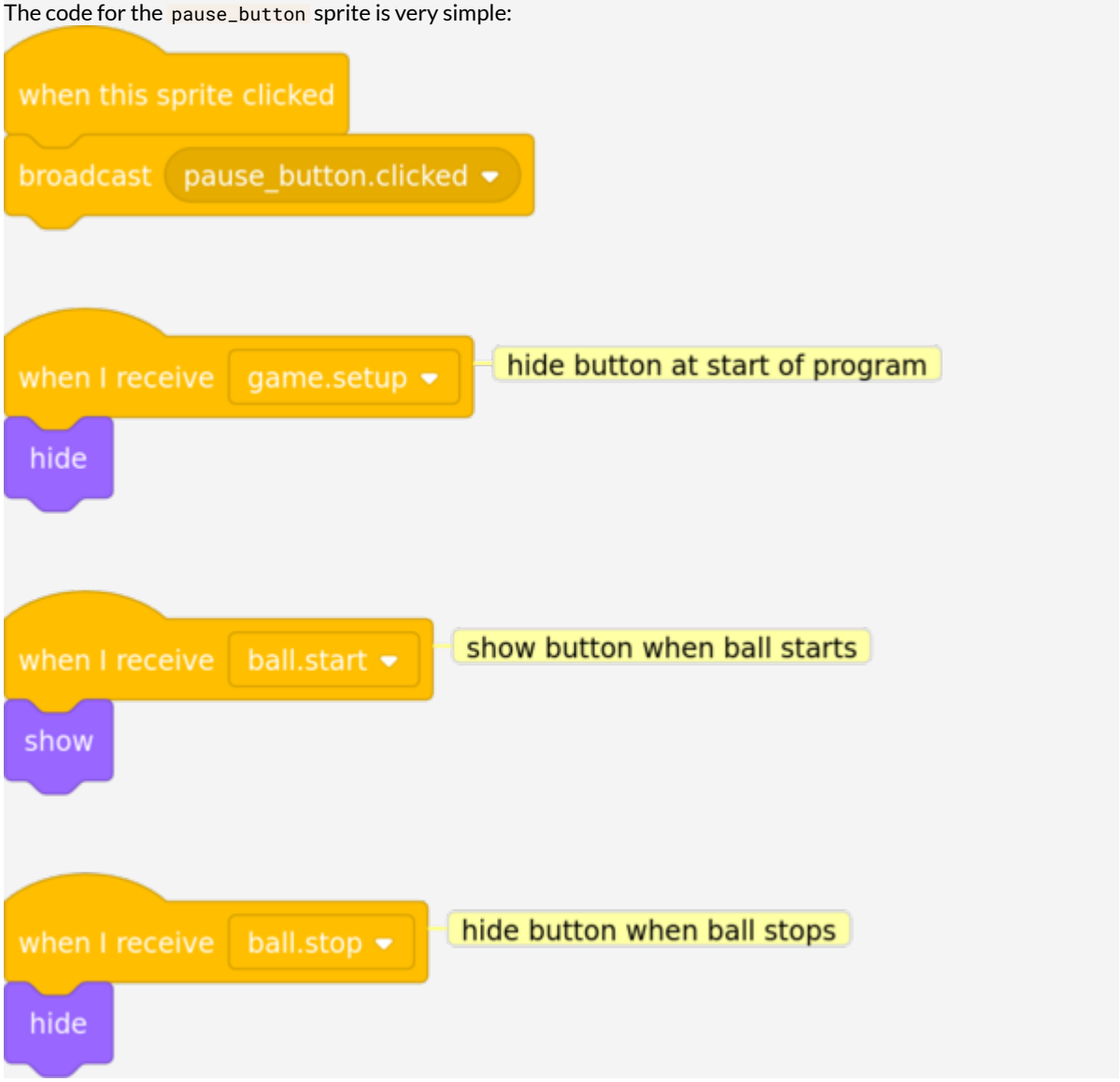
In the `stage`:



`ball`:

It turned out to be a simple bug fix: only pause the game when the ball is in play (if not, just ignore the request to pause).

The code for the `pause_button` sprite is very simple:



Task

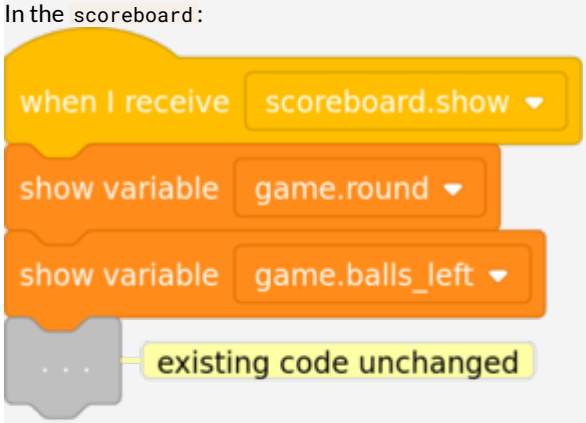
The final part of this challenge is to let the player know which round they are playing, and to allow them to change the level of difficulty. Let's add both of those to the scoreboard now.

It's up to you how you choose to arrange the scoreboard — you may need to adjust the `scoreboard` sprite's costume to make it big enough to fit everything on. I decided to put the current round at the top, then the number of balls left, and then the difficulty buttons. I had to move the `scoreboard.message` downwards (to *y* position −110) to fit everything in. Scratch makes this nice and easy as we can move the various elements around on screen (either by dragging the sprites or by adjusting their *x* and *y* values).

Once you're happy with the layout of your scoreboard, tweak its code to show and hide the new elements you've just added.

See my code:

In the `scoreboard`:

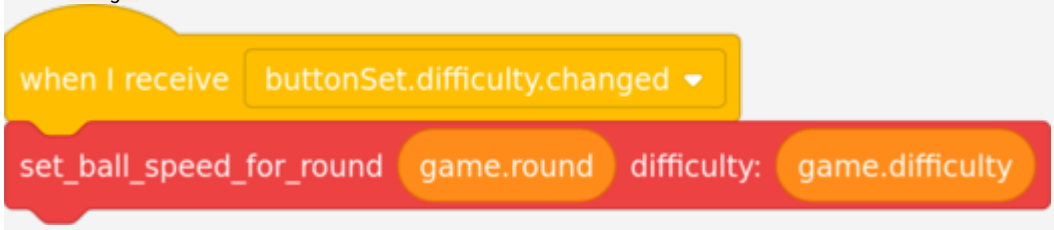


There are now just a couple of loose ends to tie up:

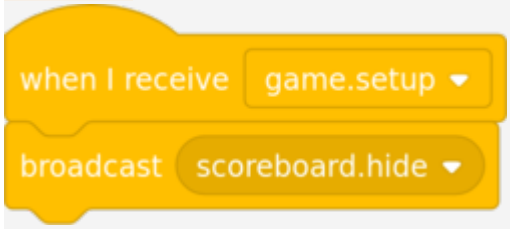
1. When the player changes the difficulty level, we need to adjust the ball speed to match the new difficulty.
2. The `bat` should only be active during a round.
3. Tidy up the display by showing and hiding various sprites at the appropriate points in the game:
    - The `scoreboard` should be hidden at the start of the program (it is already shown when triggered by the `scoreboard.show` event).
    - The `bat`, `ball` and `water` should only be shown during the round; they should be hidden when we show the *round completed*, *game lost* or *game completed* backdrops.

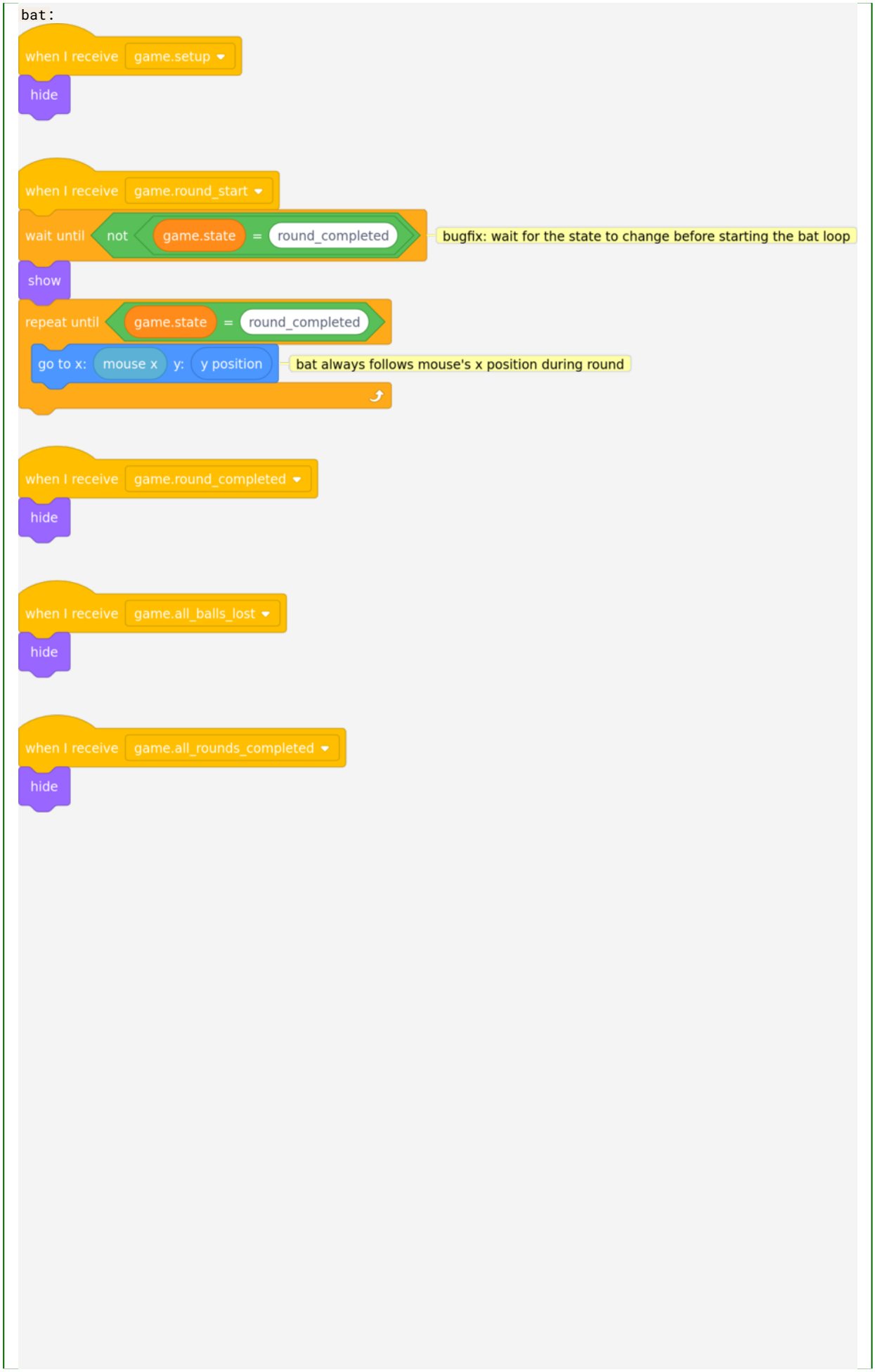
See my code:

In the `stage`:

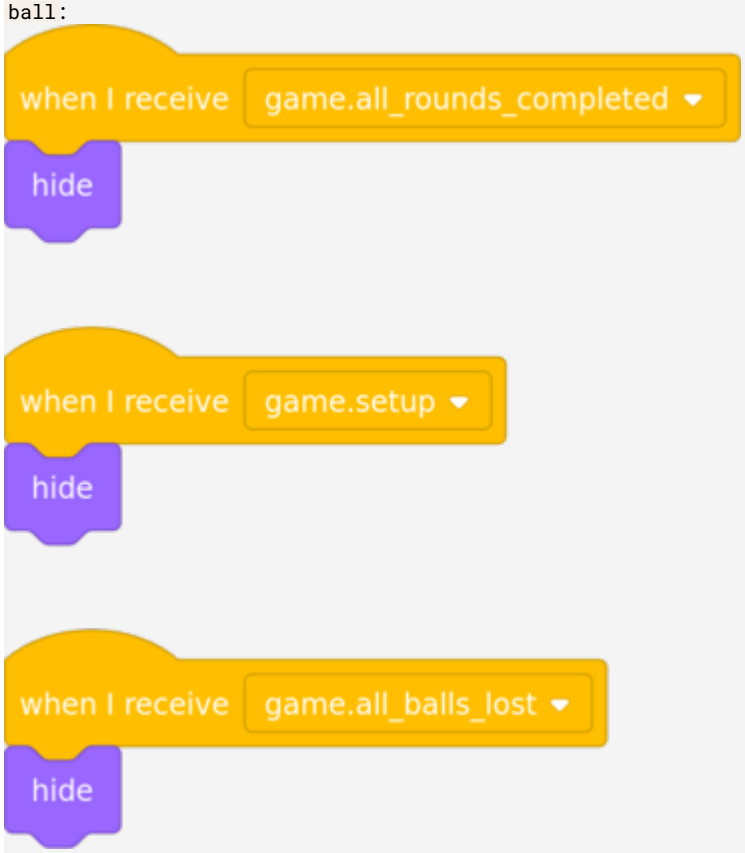


`scoreboard`:

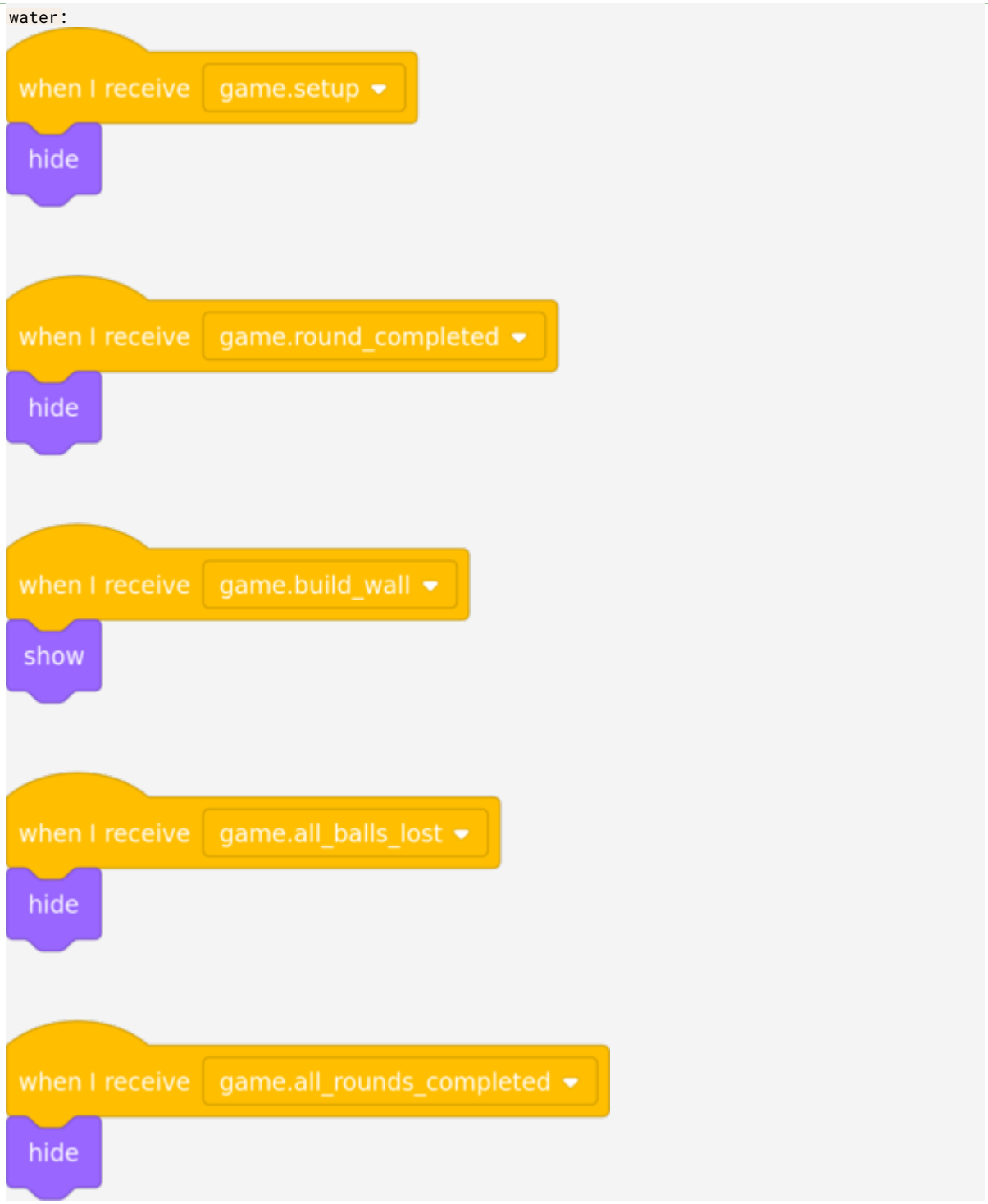



bat :
when I receive game.setup
hide
when I receive game.round_start
wait until not game.state = round_completed
bugfix: wait for the state to change before starting the bat loop
show
repeat until game.state = round_completed
go to x: mouse x y: y position
bat always follows mouse's x position during round
when I receive game.round_completed
hide
when I receive game.all_balls_lost
hide
when I receive game.all_rounds_completed
hide

```
ball:
```


when I receive game.all_rounds_completed
hide
when I receive game.setup
hide
when I receive game.all_balls_lost
hide

```
water:
```

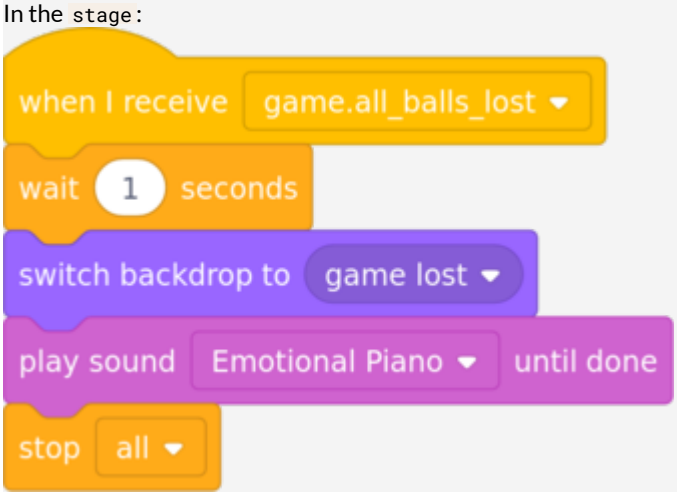


5.4.4. An extra enhancement

While I was coding this part of the game I made one other small change which is not directly related to this challenge, but I include it here for the sake of completeness: I added some music (the `Emotional Piano` library sound) when the player loses the game.

See my code:

In the `stage`:



5.5. All challenges completed

That's the end of the challenges section, and (sadly) also the end of the guided tutorial. If you've kept with it all the way to the end, thank you and well done: I hope you have found it interesting and learned a lot from it.

If you want to take the game further, read on to the next chapter for some ideas.

6. Ideas for extensions and improvements to the game

This chapter contains a few thoughts and ideas for improving the game.

6.1. Visual improvements

I'm sure you will agree that there is plenty of room to improve the game's visual appeal (as I am definitely no artist). The costumes of various sprites could be prettier, in particular the bat and bricks, and the backdrops could be made more beautiful.

If you feel the urge to have a go at improving the visual presentation of the game, I would love to see what you come up with.

6.2. New features

In no particular order, here are some ideas for new features which could be added to the game.

- Make the player hit each brick 2 or 3 times before it breaks
    - the brick would need additional costumes to indicate how many times it has been hit (perhaps slightly cracked after one hit, very cracked after two hits)
    - each clone of the brick would need to count how many times it has been hit (or how many more hits are needed to break it)
- As the game progresses to later rounds, we could introduce gaps in the wall, either random or to a set pattern, to make it harder to predict the path of the ball.
- Implement better collision detection
    - allow the player to influence the direction of the ball by hitting it with a different part of the bat
    - detect which edge of a brick the ball has hit, and make it bounce off more realistically
- Allow the player to collect accessories (sometimes called power-ups [https://en.wikipedia.org/wiki/Power-up]) to enhance their bat's capabilities. Accessories could include:
    - a wider bat which makes it easier to hit the ball
    - a much narrower bat (the player should avoid this if possible)
    - a sticky bat: when the ball touches the bat, it sticks to it and the player can move the bat and ball before launching the ball again
    - an extra ball ("life") added to the player's number of balls left
    - one that makes the ball move faster until it's lost
    - an extra ball in play, so that the player has to deal with two balls (or more) at once
        - we could implement this by cloning the ball sprite: each ball would then have its own position and direction
        - we would have to count the number of balls in play, and only lose the ball when the last ball on screen drops into the water
    - a cannon which is added to the bat which can fire upwards and knock out bricks
    - a detonator which blows up all the remaining bricks and therefore completes the round
        - this power-up would be very rare
        - there are possibilities for impressive visual and sound effects when detonation occurs
    - accessories could be dropped from the wall when a brick is broken
        - this could happen at random times
        - or the wall could contain special bricks which drop certain power-ups; for example, pink bricks could drop one type of power-up, blue bricks could drop another, and so on
    - the player must catch the dropped power-up with the bat
    - Do power-ups only last until the current ball is lost? Or does the player keep them for the rest of the round or the rest of the game?

- Introduce a scoring system
    - the game could award points for every brick broken
    - the number of points awarded could increase if the game has several rounds e.g. 1 point per brick in round 1, 2 points on round 2 etc
    - points could be related to the speed of the ball e.g. `ball.speed` points per brick; faster speeds would gain more points

Appendix 1: List Of Variables

`ball.in_motion`
: Flag (see page 72) which records whether or not the ball is moving: a value of `0` means *is not moving*, a value of `1` means *is moving*.

`ball.speed`
: Controls how many steps the ball moves at a time. Higher values cause the ball to move faster. A value of `10` is reasonable for a game that's not too easy but not too hard.

`brick.clone_complete`
: Flag (see page 72) which signals whether or not the `brick` sprites `when I start as a clone` script has completed.

`wall.num_bricks`
: Keeps count of the number of bricks remaining in the wall. Increases by 1 when a brick is added to the wall, and decreases by 1 every time the player knocks a brick out of the wall.

`wall.x` & `wall.y`
: Point to the *x* and *y* position on the stage where the next brick is to be placed. See section: block `build_row` (see page 19).

(wall sprite only): `brick.width` & `brick.height`
: Visible only to the `wall` sprite. Record the dimensions of a single brick. Allows the `wall` to place individual bricks side by side and rows of bricks on top of one another.

(wall sprite only): `wall.row`
: Records how many complete rows of bricks have been added to the wall. Set to `0` before we start building; increases after each row is complete. Allows the wall to know when it has added the required number of rows and stop building.

`game.balls_left`
: Keeps count of how many balls the player has remaining. Once the player runs out of balls the game is lost. See section Challenge: Give the player three balls (see page 41).

`scoreboard.message`
: Specifies the text that the scoreboard will pass to the 

block i.e. the message that will be shown to the player. See section Challenge: Give the player three balls (see page 41).

`game.difficulty`
: Stores the current level of difficulty as set by the player: `0` for *easy*, `1` for *medium* or `2` for *hard*. See section Challenge: Give the game more than one round (see page 49).

`game.round`
: Keeps track of the round being played. Set to `0` in the `game.setup` block; increases before the start of each round. See section Challenge: Give the game more than one round (see page 49).

`game.last_round`
: Specifies the final round of the game. If `game.round` is equal to `game.last_round` the final round is being played; if `game.round` is greater than `game.last_round` then the player has completed the entire game. See section Challenge: Give the game more than one round (see page 49).

`game.state`
: A text representation of the current state of the game. Possible values are:

  - `title_screen`: indicates the game is at the opening title screen
  - `round_start`: indicates the game is at the start of a round
  - `in_play`: indicates the ball is in play
  - `pause`: indicates the game is paused
  - `round_completed`: indicates the player has just completed a round
  - `all_rounds_completed`: indicates the player has just completed the whole game
  - `all_balls_lost`: indicates the player has just lost their last ball

  See section Challenge: Give the game more than one round (see page 49).

Appendix 2: List of Events/Messages

Message	Meaning	Broadcast by	Received by & Action taken
`game.setup`	program start: set up	`stage`	`bat`: make self visible
`game.build_wall`	wall about to be built	`stage`	`wall`: start building
`game.round_start`	round about to start or restart after ball lost	`stage`, `ball`	`ball`: set start position & direction, set `ball.in_motion` flag to *no* `bat`: follow mouse pointer's *x* position
`game.round_completed`	player demolished last brick	`brick`	`stage`: change backdrop, play *tada* sound `ball`: stop moving, hide
`game.all_balls_lost`	player lost last ball in water	`ball`	`stage`: change backdrop, end program `brick`: delete all clones `bat`: hide `ball`: hide
`ball.start`	ball about to start moving	`stage`, `bat`	`ball`: set `ball.in_motion` flag to *yes*, hide scoreboard, start moving `bat`: start checking if ball touches bat `brick`: start checking if ball touches brick `water`: wait until ball hits water
`ball.stop`	ball about to stop moving	`stage`, `ball`	`ball`: set `ball.in_motion` flag to *no*
`ball.hit_bat`	ball hit the bat	`bat`	`ball`: bounce
`ball.hit_brick`	ball hit a brick	`brick`	`ball`: bounce `brick`: play *bass drum* sound, disappear, check if any more bricks remain
`ball.hit_water`	ball fell into water	`water`	`ball`: stop moving, play *splash* sound, decrease count of balls left, check if any balls remain
`water.start`	start water wave effect	`stage`	`water`: start wave animation
`scoreboard.show`	scoreboard to be displayed	`stage`, `ball`	`scoreboard` & `scoreboard_message`: show scoreboard
`scoreboard.hide`	scoreboard to be hidden	`stage`, `ball`	`scoreboard` & `scoreboard_message`: hide scoreboard
`game.all_rounds_completed`	player completed final round	`stage`	`stage`: change backdrop, play congratulation sounds `ball`: hide `bat`: hide `water`: hide
`game.pause`	player has paused game	`stage`	`ball`: stop moving
`game.continue`	player has resumed game	`stage`, `bat`, `scoreboard`	`stage`: move on to the next part of the game (or resume after pause)
`pause_button.clicked`	player has clicked on pause button	`pause_button`	`stage`: pause game
`buttonSet.difficulty.changed`	player has changed difficulty setting	`buttonSet.difficulty`	`stage`: update value of `ball.speed` for new difficulty level

Appendix 3: Definitions

algorithm

An *algorithm* is a set of steps to complete a task which the computer should follow in order. For example, this might be an algorithm to describe making a sandwich:

1. Cut 2 slices of bread
2. Repeat for each slice:
    - Spread butter on one side of the slice
3. Lay filling onto *one* of the buttered sides
4. Lay the other piece of bread on top, with the buttered side facing the filling

bug

A *bug* is a mistake in a computer program that causes the computer to do something the programmer did not expect it to do. Tracking down and fixing bugs is known as *debugging*. See the Wikipedia entry [https://en.wikipedia.org/wiki/Software_bug] .

crop

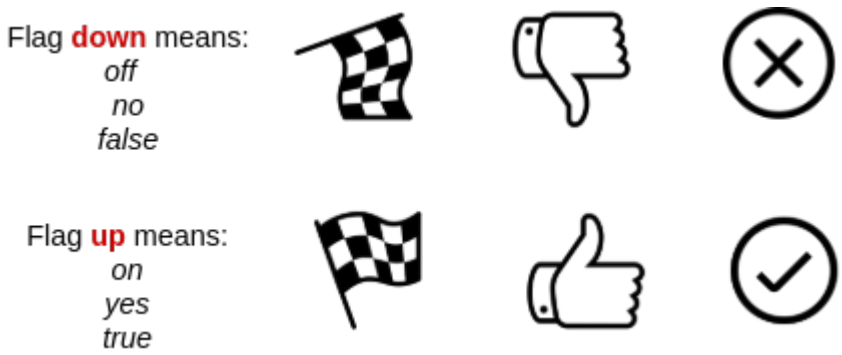
*Crop*ping an image or video means cutting off unwanted parts, usually from the edges. See the Wikipedia entry [https://en.wikipedia.org/wiki/Cropping_(image)] .

event

An *event* is something which causes a computer program to take some action. It can be triggered by a user (e.g. by pressing a key, clicking the mouse or tapping a touchscreen) or by the computer (e.g. by some condition in the code). See the Wikipedia entry [https://en.wikipedia.org/wiki/Event_(computing)] .

flag

A *flag* is a type of variable that has only two possible states: it is either on or off. You can think of the flag as either being *up* (or *on*, or meaning *yes*) or *down* (or *off*, or *no*).



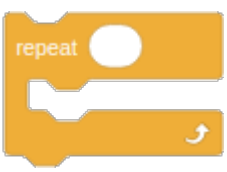
Flag variables

This type of variable is also known as a Boolean [https://en.wikipedia.org/wiki/Boolean_data_type] variable.

loop

A *loop* is a section of code that repeats more than once. In Scratch we use the 

,



and 

blocks to loop.

parameter

A *parameter* (also known as an *argument*) is a piece of information that you pass to a block of code to tell it more precisely how to behave. For example, if you created a Scratch block called `say hello (n) times`, `n` would be a parameter: the value of `n` tells the block how many times to say "hello".

Scratch allows us to define our own blocks with parameters: Scratch version 3 calls these *inputs* to the block.

See the Scratch wiki entry for input [https://en.scratch-wiki.info/wiki/Input] and the Wikipedia entry for parameter [https://en.wikipedia.org/wiki/Parameter_(computer_programming)] .

pixel

A *pixel* is a single dot on a computer display. It stands for *Picture Element*. In Scratch the size of the stage and the sprites are measured in pixels. For a much more detailed explanation see the Wikipedia entry for pixel [https://en.wikipedia.org/wiki/Pixel] .

validation

Validation is the process of checking that an input (coming from a human or another computer process) is an acceptable value. For example, if the computer program is expecting a date and a user types *apple* then the program needs to reject this as invalid and let the user know. See the Wikipedia entry [https://en.wikipedia.org/wiki/Data_validation] .

variable

A *variable* is a space in a computer program that can store a piece of information such as a number or a string of text. It's so called because the value of the variable can vary as the program runs. See the Scratch wiki entry [https://en.scratch-wiki.info/wiki/Variable] and the Wikipedia entry [https://en.wikipedia.org/wiki/Variable_(computer_science)] .

Appendix 4: Acknowledgements and Attributions

Here is a list of resources used in this tutorial and the game. Many thanks to the authors for making their work freely available.

Scratch [https://scratch.mit.edu/about] : the brilliant coding tool from the Lifelong Kindergarten Group at the MIT Media Lab

 External link icon [https://icons8.com/icon/60664/external-link] by Icons8 [https://icons8.com]

Icons by Freepik [https://www.flaticon.com/authors/freepik] from flaticon [https://www.flaticon.com/] :

 Coding icon [https://www.flaticon.com/free-icon/code_2920277]

 Finger ribbon icon [https://www.flaticon.com/free-icon/hand-finger-with-a-ribbon_30212]

 Challenge icon [https://www.flaticon.com/free-icon/summit_1632840]

 Test icon [https://www.flaticon.com/free-icon/debugging_1541504]

 Hint icon [https://iconmonstr.com/light-bulb-18-svg/] by Alexander Kahlkopf of iconmonstr [https://www.iconmonstr.com]

 Note icon [https://www.flaticon.com/free-icon/notepad_117869] by Vectors Market [https://www.flaticon.com/authors/vectors-market] from flaticon [https://www.flaticon.com/]

 Pause button [https://www.flaticon.com/free-icon/pause_890642] by Pixel perfect [https://www.flaticon.com/authors/pixel-perfect] from flaticon [https://www.flaticon.com/]

Water wave sprite costume adapted from this looping water animation [https://www.youtube.com/watch?v=OjlAyPSeOvg] created by Bridgehead Productions [https://www.bridgeheadproductions.com]

The title screen uses:

cricket ball image [https://www.transparentpng.com/download/cricket-ball-clipart-photos_15715.html] from TransparentPng [https://www.transparentpng.com]

broken glass image [https://clipground.com/pic/getsecond?url=broken-glass-clipart-14.jpg] from Clipground [https://clipground.com]

cracked glass texture [https://www.pikpng.com/pngvi/ioTJhJi_cracked-glass-texture-png-sketch-clipart/] from PikPng [https://www.pikpng.com]

This document was produced using pandoc [https://pandoc.org] universal document converter.

The PDF version was produced with weasyprint [https://weasyprint.org] HTML to PDF converter.

The Scratch code images were produced with ScratchBlocks [http://scratchblocks.github.io] .

Changelog

Version 1.3 published 22 July 2020

- Suggest remix to make copy of template project
- Add ScratchBlocks to acknowledgements
- Reformat changelog

Version 1.2 published 11 July 2020

- Add Challenge: Give the game more than one round
- Add brief *End of challenges* section
- Fixes:
  - Select costume by number with `switch costume to (index)` rather than `next costume` in a loop
  - Can test a block just by single clicking it

Version 1.1 published 1 July 2020

- Add title screen to tutorial, template project and example projects
- Add licence notification

Version 1.0 published 28 June 2020:
Initial version