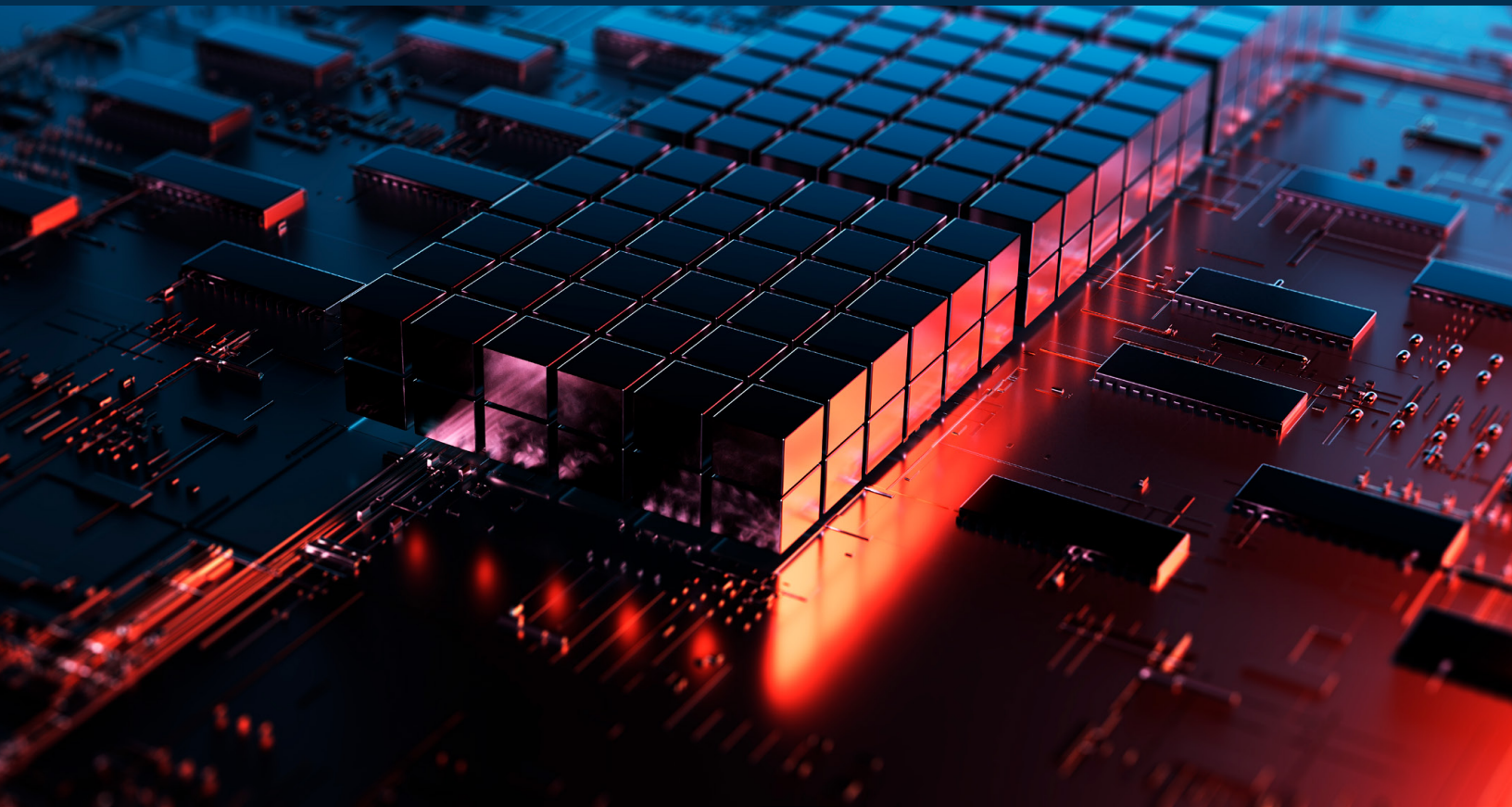


→ E-BOOK



# Create modular game architecture in Unity with ScriptableObjects



# Contents

<b>Introduction</b>	<b>5</b>
<b>What are ScriptableObjects?</b>	<b>6</b>
Serialization	8
<b>ScriptableObjects versus MonoBehaviours</b>	<b>10</b>
Comparison	11
Callbacks and messages	12
Files	13
YAML ain't markup language	14
Creation and lifecycle	15
Destroying ScriptableObjects	16
<b>Data containers</b>	<b>17</b>
ScriptableObject data versus persistent data	20
Reducing duplicate data	20
Design patterns	21
Refactoring example	23
Code conventions in this guide	24
Custom Inspectors	25
Architectural benefits	27
ScriptableObject variables	29
Dual serialization	30
Protect your data	33
<b>The Extendable enums pattern</b>	<b>34</b>
Enum-like categories	34
Extending behavior	36

<b>Pattern: Delegate objects</b> .....	<b>39</b>
Delegates versus events.....	39
ScriptableObjects methods .....	40
Modifying ScriptableObject data .....	41
Pluggable behavior .....	42
Gameplay AI with ScriptableObjects.....	43
Example: Audio delegates .....	43
The glorious ScriptableObject revolution .....	44
<b>The Observer pattern</b> .....	<b>45</b>
Avoiding singletons.....	45
ScriptableObject-based events.....	47
Example: Event channels .....	49
System.Action or UnityAction .....	49
Debugging event channels.....	54
Example: InputReader.....	55
Static versus non-static events.....	58
<b>The Command pattern</b> .....	<b>59</b>
ScriptableObjects or C# classes? .....	63
<b>The Runtime Set pattern</b> .....	<b>64</b>
Basic Runtime Set.....	64
Generic version .....	67
Fun facts about foo and bar.....	69
<b>Explore the sample project</b> .....	<b>70</b>
<b>Conclusion</b> .....	<b>72</b>

<b>More resources .....</b>	<b>73</b>
Documentation .....	73
Technical e-books from Unity .....	73
From Unite .....	74
More project examples .....	74
For game designers .....	74
Professional training .....	75

# Introduction

You will often hear ScriptableObjects described as “data containers.” That label, however, doesn’t quite do them justice. Applied correctly, ScriptableObjects can also help you speed up your Unity workflow, reduce memory usage, and simplify your code architecture.

This guide assembles tips and tricks from professional developers for deploying ScriptableObjects in production. These include examples of how to apply them to specific design patterns and how to avoid common pitfalls.

ScriptableObjects can help promote clean coding practices by separating data from logic. They make it easier to make changes without causing unintended side effects, improving testability and modularity.

Because you can work with them interactively in the Editor, you’ll discover that ScriptableObjects are especially useful for collaboration between programmers and non-programmers, such as artists and designers. In this guide we will cover several techniques and ways to leverage Scriptable Objects. We hope that some of these can complement your existing workflow and streamline your project setup.

Let’s explore the unsung hero of game architecture, the humble ScriptableObject.

# What are ScriptableObjects?

A [ScriptableObject](#) is a Unity object that's not part of a `GameObject` instance. You can use it to create a custom class with its own variables and methods, but with less overhead than a `MonoBehaviour`.

A `ScriptableObject` does not have a `Transform` and exists outside of the Scene Hierarchy. Instead, it lives at the project level as an asset, much like a material or 3D model.

You can declare a `ScriptableObject` like this:

```
[CreateAssetMenu(fileName="MyScriptableObject")]
public class MyScriptableObject: ScriptableObject
{
    public int someVariable;
}
```

As you can see in the code above rather than deriving from `MonoBehaviour`, you inherit from `ScriptableObject`.

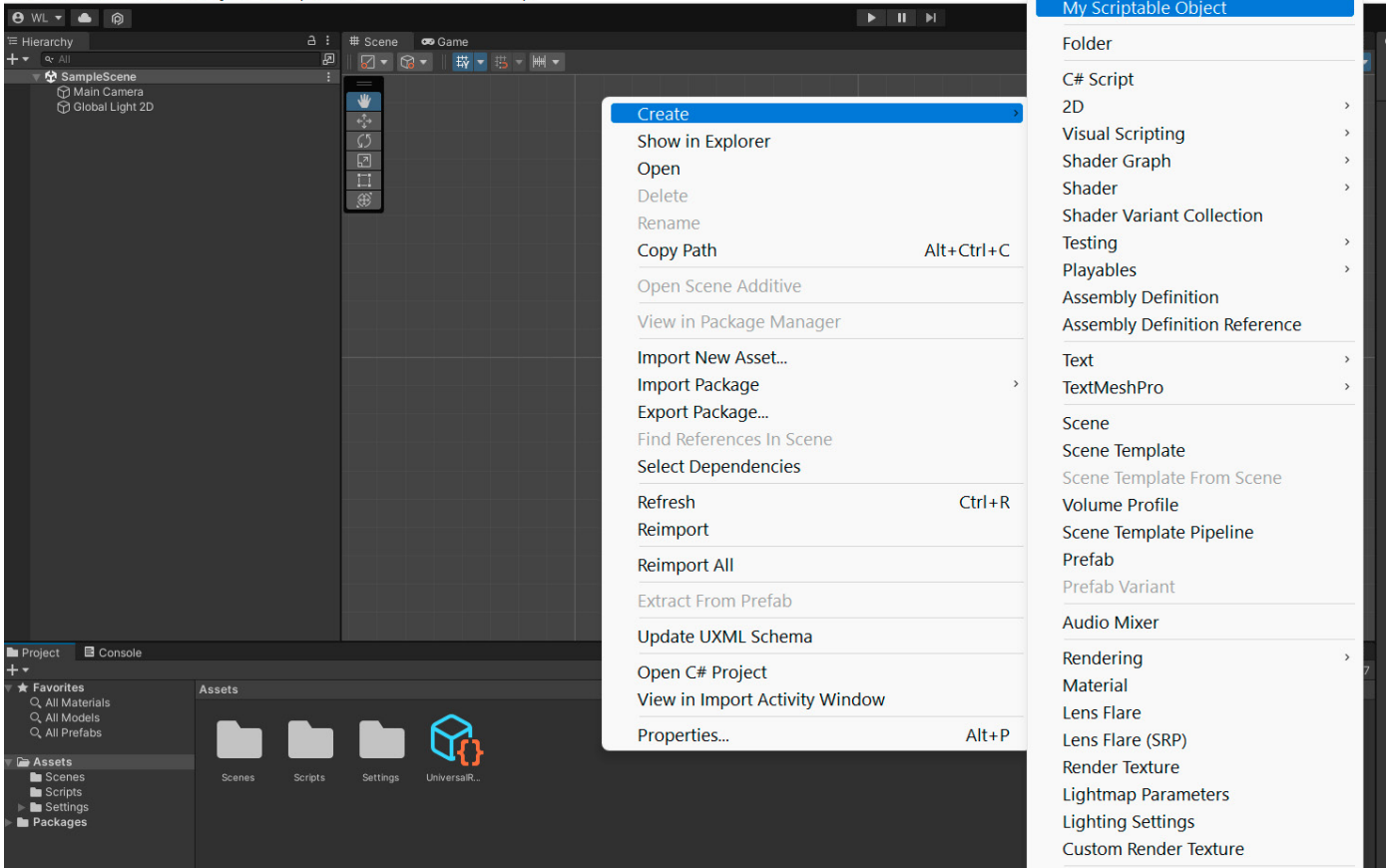
You can't use this directly on a `GameObject`. Instead, the `CreateAssetMenu` attribute gives you an extra action in your menus.



Navigate to **Assets > Create > MyScriptableObject** (or right-click in the Project window), and you can instantiate a custom asset from your ScriptableObject class.

GameSystemCookbook - SampleScene - Windows, Mac, Linux - Unity 2021.3.7f1 Personal <DX11>

File Edit Assets GameObject Component Jobs Window Help



Creating a ScriptableObject

Any other script can then reference this ScriptableObject asset from any scene, using a field:

```
public class MyMonoBehaviour : MonoBehaviour
{
    public ScriptableObject soInstance;
}
```

ScriptableObjects are especially useful for anything that doesn't need to change at runtime.



Because Unity treats ScriptableObjects as first-class objects, you can:

- Store them in variables
- Dynamically create or destroy them at runtime
- Pass them as arguments
- Return them from a method
- Include them in data structures
- Serialize/deserialize them

This last bullet point highlights one of ScriptableObjects's key features: the ability to appear in the Inspector. This means that its fields are easy to read and modify in the Editor.

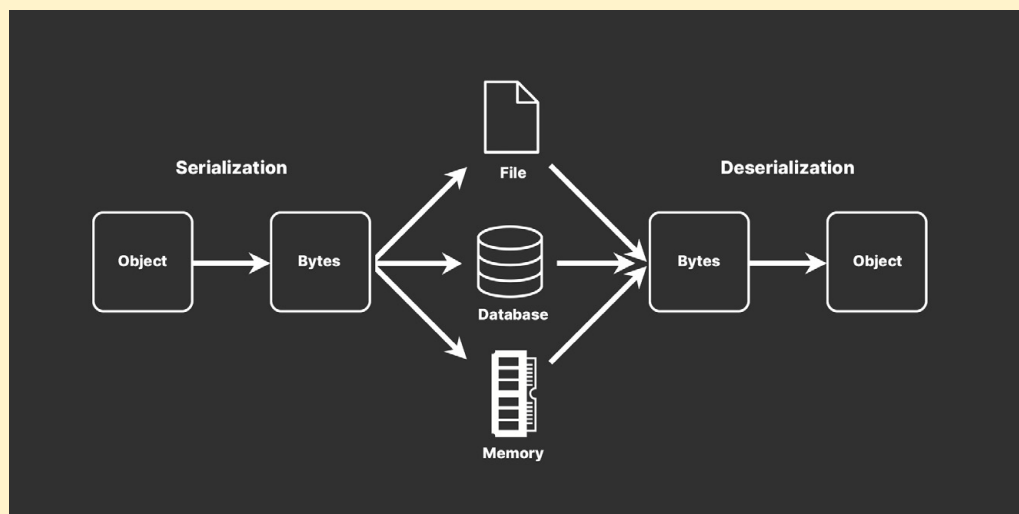
Change values in a ScriptableObject at runtime, and your game application updates immediately. Exit Play mode, and those values remain in place. This makes them useful for game designers who need to [balance game settings](#) without having to write code. As a plus, ScriptableObjects can often store changes while the application is running. This offers a few advantages over using MonoBehaviours alone.



## Serialization

[Serialization](#) is the automatic process of transforming data structures or object states into a format that's easier to store and reconstruct later. Unity's serialization backend takes data that's scattered over memory and then lays it out sequentially.

This reorganized data stream then can be stored in a database, a file, or memory. "Deserialization" is the reverse process.



Serialization is the process of converting an object into a stream of bytes to store the object or transmit it to memory, a database, or a file.





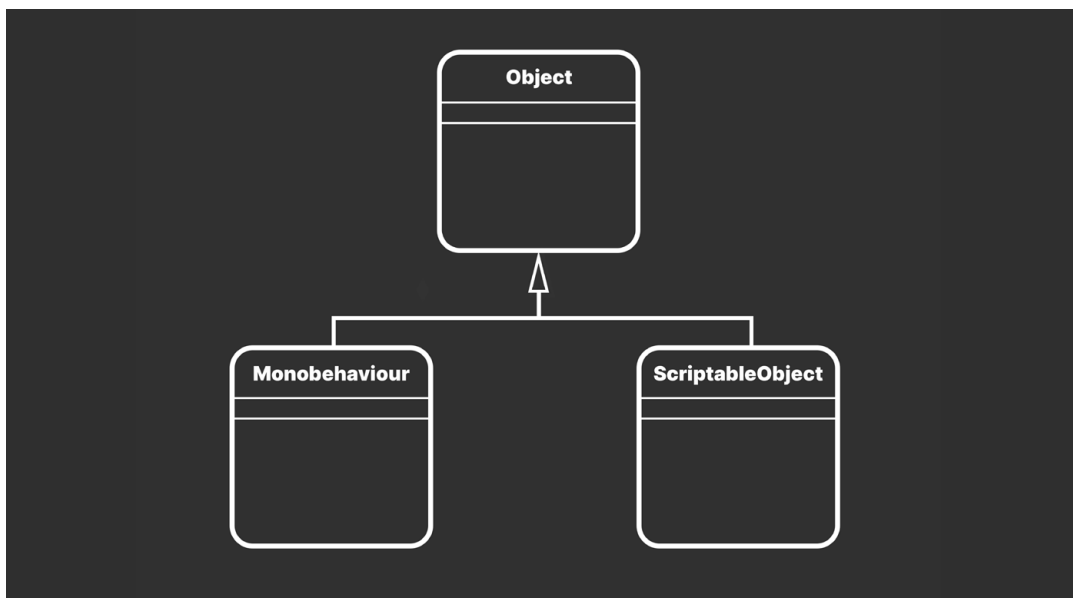
Although memory layout is easy to overlook in C# development, we should be aware of several built-in Unity features that use serialization:

- **Saving and loading:** If you open a **.unity** scene file with a text editor and have set unity to “force text serialization,” the serializer is run with a **YAML** backend.
- **The Inspector window:** This interface doesn’t talk to the C# API to figure out the values of whatever it’s inspecting. Instead, it asks the object to serialize itself and displays the serialized data.
- **Prefabs:** Internally, a **prefab** is the serialized data stream of GameObjects and components. A prefab instance is a list of modifications that should be made on top of the serialized data.
- **Instantiation:** When you instantiate a prefab (or a GameObject that lives in the scene), you serialize the object, create a new object, and then deserialize the data onto the new object.

For more information about serialization in Unity, see [this blog post](#) or watch “[How Unity’s Serialization system works.](#)”

# ScriptableObjects versus MonoBehaviours

On the surface, ScriptableObjects are simple. The API sports only a few methods. In this case, that's a good thing. Simplicity means less can go wrong.



Unity Object UML

Like MonoBehaviour, the ScriptableObject class derives from [UnityEngine.Object](#) class.



## Comparison

Probably the best way to understand ScriptableObjects is to compare them with their siblings, MonoBehaviours. This chart breaks down their similarities and differences.

MonoBehaviour	ScriptableObject
<b>MonoBehaviours and ScriptableObjects are both scripts.</b>  MonoBehaviour and ScriptableObject classes derive from UnityEngine.Object.	
<b>MonoBehaviours receive callbacks from Unity.</b>  Connect your methods to the game engine's player loop by naming them according to MonoBehaviour's <a href="#">event functions</a> like Update().  e.g., Start, Awake, Update, OnEnable, OnDisable, OnCollisionEnter	<b>ScriptableObjects do not receive most Unity lifecycle callbacks from Unity like Update, Start or FixedUpdate.</b>  ScriptableObjects support a limited number of event functions, including Awake, OnEnable, OnDestroy, and OnDisable at runtime. The Editor also calls OnValidate and Reset from the Inspector.  You can create other methods on a ScriptableObject, but the player loop does not invoke them automatically.
<b>MonoBehaviours must be attached to GameObjects at runtime.</b>  If you create one at runtime, use the AddComponent API.	<b>ScriptableObjects are not attached to any specific GameObject.</b>  Save ScriptableObjects into their own asset files at the Project level. Then, reference the ScriptableObject asset from a MonoBehaviour or other script.
<b>When we do save them, we save MonoBehaviours data into Scenes and prefabs.</b>	<b>Each ScriptableObject instance can be saved into its own file at the Project level.</b>
<b>In the Editor, changes to MonoBehaviour values reset when exiting Play mode.</b>	<b>In the Editor, changes to ScriptableObject values do <u>not</u> reset when exiting Play mode.</b>  <b>In a standalone build, changes to ScriptableObject values at runtime are <u>not</u> saved.</b>
<b>MonoBehaviours and ScriptableObjects are both serializable and can be viewed in the Inspector.</b>	



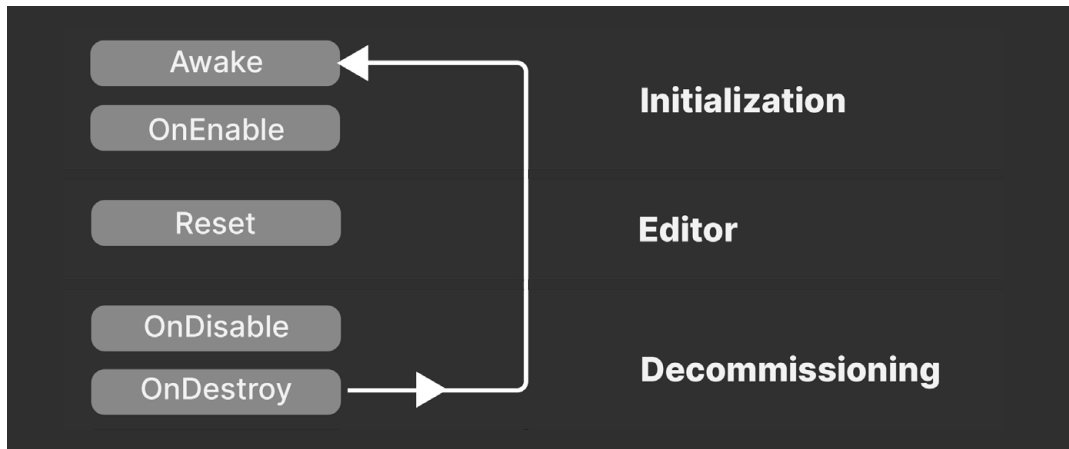
## Callbacks and messages

ScriptableObjects have a subset of the event functions available to MonoBehaviours. You can create your own methods in your ScriptableObjects too, but you need to call them yourself. The table below shows only the methods that will be called automatically in the PlayerLoop.

Event function (runtime)	When it executes
<b>Awake</b>	<p>This is called as the ScriptableObject script starts, similar to MonoBehaviour's Awake callback.</p> <p>This also executes when the game is launched or if a scene loads with a reference to the ScriptableObject asset.</p>
<b>OnEnable</b>	<p>This is called when the ScriptableObject is loaded or instantiated, immediately after the Awake callback.</p> <p>OnEnable executes during the ScriptableObject.CreateInstance or after successful script recompilation.</p>
<b>OnDisable</b>	<p>This is called when the ScriptableObject goes out of scope. This happens if you load a Scene without references to the ScriptableObject asset or right before the ScriptableObject's OnDestroy.</p> <p>Unity also executes OnDisable before script recompilations. When entering Play mode, OnDisable runs right before OnEnable.</p>
<b>OnDestroy</b>	<p>This is called when something destroys the ScriptableObject, either deleting it in the Editor or from code.</p> <p>If you've created the ScriptableObject at runtime, OnDestroy also invokes when the application quits or if the Editor exits Play mode. Note: This only destroys the native C++ part of the object. See Lifecycle and Creation for more information.</p>
Editor-only functions	When it executes
<b>OnValidate</b>	OnValidate executes when the script is loaded or a value changes in the Inspector. This can be used to ensure that your data stays within a certain range.
<b>Reset</b>	Reset invokes when you hit the Reset button in the Inspector context menu.

To destroy a ScriptableObject, remove it from the Editor or call Destroy/DestroyImmediate at runtime.

Here's a brief overview of a ScriptableObject's event functions and life cycle. Compare this with the order of execution of [MonoBehaviour event functions](#), starting from the top.



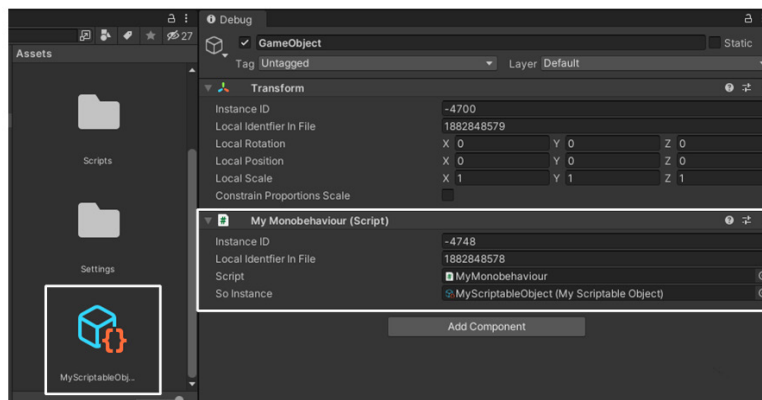
ScriptableObject event functions and execution order

## Files

One of their biggest differences between MonoBehaviours and ScriptableObjects is how they save their data.

Unity serializes MonoBehaviours within either a Scene or a prefab file. The saved data contains:

- The MonoBehaviour itself
- The attached GameObject
- Its Transform
- Any other components and MonoBehaviours on the attached GameObject



MonoBehaviour attaches to GameObject

### ScriptableObject appears in project

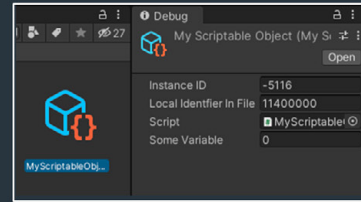
ScriptableObject versus MonoBehaviour

In contrast, Unity saves ScriptableObjects into their own asset files. These files are smaller and more compartmentalized than MonoBehaviours.



If you choose to use **Mode: Force Text** in the **Project Settings > Asset Serialization** window, you can open a ScriptableObject asset in a text editor. It might look something like this:

```
1 %YAML 1.1
2 %TAG !u! tag:unity3d.com,2011:
3 --- !u!114 &11400000
4 MonoBehaviour:
5   m_ObjectHideFlags: 0
6   m_CorrespondingSourceObject: {fileID: 0}
7   m_PrefabInstance: {fileID: 0}
8   m_PrefabAsset: {fileID: 0}
9   m_GameObject: {fileID: 0}
10  m_Enabled: 1
11  m_EditorHideFlags: 0
12  m_Script: {fileID: 11500000, guid: 3fc7a749f692b4f41923450f022d8428, type: 3}
13  m_Name: MyScriptableObject
14  m_EditorClassIdentifier:
15  someVariable: 0
16
```

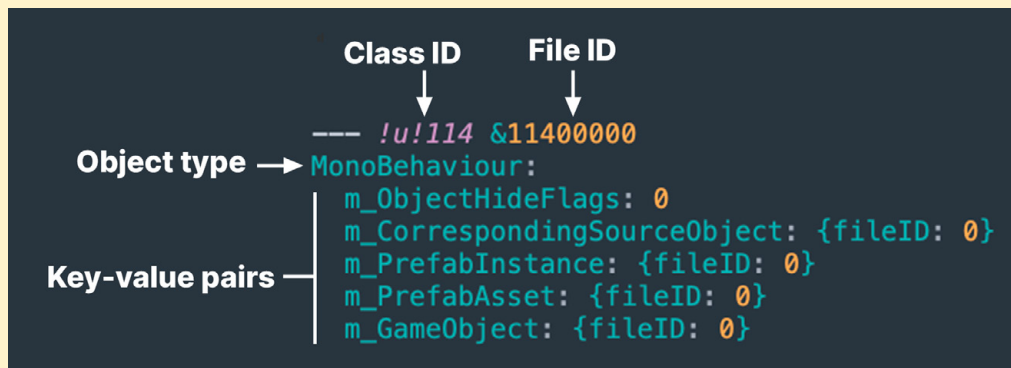


A ScriptableObject instance, serialized as text

## YAML ain't markup language

Unity uses a high performance serialization library that implements a subset of the YAML specification. This is a lightweight, easy-to-read language related to XML and JSON.

In YAML, data is organized as a hierarchy of nested elements. Each object has a Class ID, File ID, and object type. Note that ScriptableObjects use “MonoBehaviour” as their object type, instead of defining their own.



An object header in YAML

Under each object are its serialized properties, represented by key-value pairs.

For more information, read the blog post [“Understanding Unity’s serialization language, YAML”](#).



## Creation and lifecycle

The lifecycle of a ScriptableObject is similar to that of any other asset (materials, textures, and so on) in your project.

As in the previous example, apply the `[CreateAssetMenu]` attribute to your script in order to add a custom menu action to the Editor. You can optionally specify the default [fileName](#) or menu item [order](#). The following code is the most common way to create a ScriptableObject asset.

```
[CreateAssetMenu(fileName="MyScriptableObject")]  
public class MyScriptableObject: ScriptableObject  
{  
    public int SomeVar;  
}
```

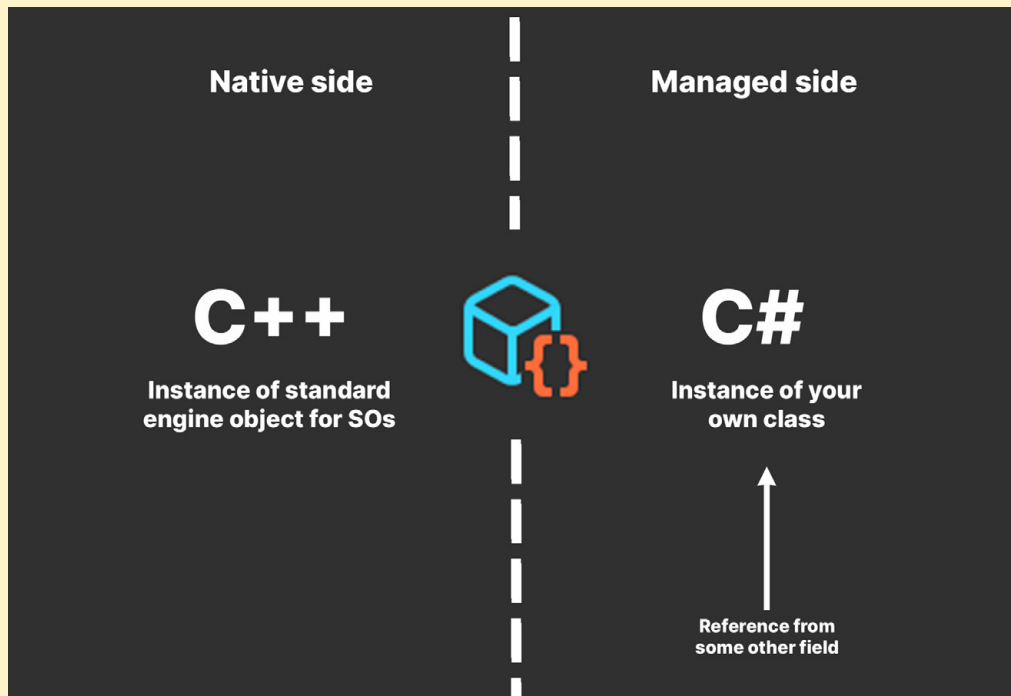
If you need to make a ScriptableObject instance at runtime, you can call the static `CreateInstance` method:

```
ScriptableObject.CreateInstance<MyScriptableObjectClass>();
```



## Destroying ScriptableObjects

Like other Unity objects, a ScriptableObject consists of a native C++ portion, as well as a C# managed portion. You can destroy the native C++ directly, but the managed part remains until the asset garbage collector (GC) clears it. The GC cleanup occurs if you change scenes or call [Resources.UnloadUnusedAssets](#).



ScriptableObjects have both a native and managed side.

Explicitly set any references to the ScriptableObject asset to null to avoid delaying garbage collection.

**Note:** It's important to do this before calling `Destroy` or `DestroyImmediate`. Otherwise, the reference to the object may be nominally marked "null" in the Editor, even if it isn't really null. GC cleanup only happens once there are no more references to the ScriptableObject.

Once you have the knack of creating and destroying your own ScriptableObjects, it's time to explore some creative ways to use them in your game application.



# Data containers

The most common use for ScriptableObjects is as data containers for shared static data, particularly for game configuration data that doesn't change at runtime.

Typical use cases of ScriptableObjects may include:

- Inventories like item type, icon, rarity, effects
- Enemy, player, or item statistics like health, damage, speed, AI parameters
- Audio collections like audio clip groups for footsteps, UI sounds, or ambient loops
- Config Files like difficulty settings, progression curves, spawn tables
- Dialogue data

At runtime, you could store this data on MonoBehaviours, but doing so can be inefficient. As you saw in the previous comparison, MonoBehaviours carry extra overhead since they require a GameObject – and by default a Transform – to act as a host. That means that you need to create a lot of unused data before storing a single value.



To see for yourself, generate a new GameObject with an otherwise empty MonoBehaviour. Then, open the serialized object in a text editor and it will look something like this:

```
GameObject:
  m_ObjectHideFlags: 0
  m_CorrespondingSourceObject: {fileID: 0}
  m_PrefabInstance: {fileID: 0}
  m_PrefabAsset: {fileID: 0}
  serializedVersion: 6
  m_Component:
  - component: {fileID: 7467558130563611466}
  - component: {fileID: 2006805663113952451}
  m_Layer: 0
  m_Name: GameObject
  m_TagString: Untagged
  m_Icon: {fileID: 0}
  m_NavMeshLayer: 0
  m_StaticEditorFlags: 0
  m_IsActive: 1
--- !u!4 &7467558130563611466
Transform:
  m_ObjectHideFlags: 0
  m_CorrespondingSourceObject: {fileID: 0}
  m_PrefabInstance: {fileID: 0}
  m_PrefabAsset: {fileID: 0}
  m_GameObject: {fileID: 338842853706088653}
  m_LocalRotation: {x: 0, y: 0, z: 0, w: 1}
  m_LocalPosition: {x: -1.1780801, y: -2.6573246, z: -0.01486098}
  m_LocalScale: {x: 1, y: 1, z: 1}
  m_ConstrainProportionsScale: 0
  m_Children: []
  m_Father: {fileID: 0}
  m_RootOrder: 0
  m_LocalEulerAnglesHint: {x: 0, y: 0, z: 0}
--- !u!114 &2006805663113952451
MonoBehaviour:
  m_ObjectHideFlags: 0
  m_CorrespondingSourceObject: {fileID: 0}
  m_PrefabInstance: {fileID: 0}
  m_PrefabAsset: {fileID: 0}
  m_GameObject: {fileID: 338842853706088653}
  m_Enabled: 1
  m_EditorHideFlags: 0
  m_Script: {fileID: 11500000, guid: 4d1457d233f8d479795a30f859537d5f,
  m_Name:
  m_EditorClassIdentifier:
```

A new GameObject with a barebones MonoBehaviour

Compare that with an empty ScriptableObject and you see its notably leaner:

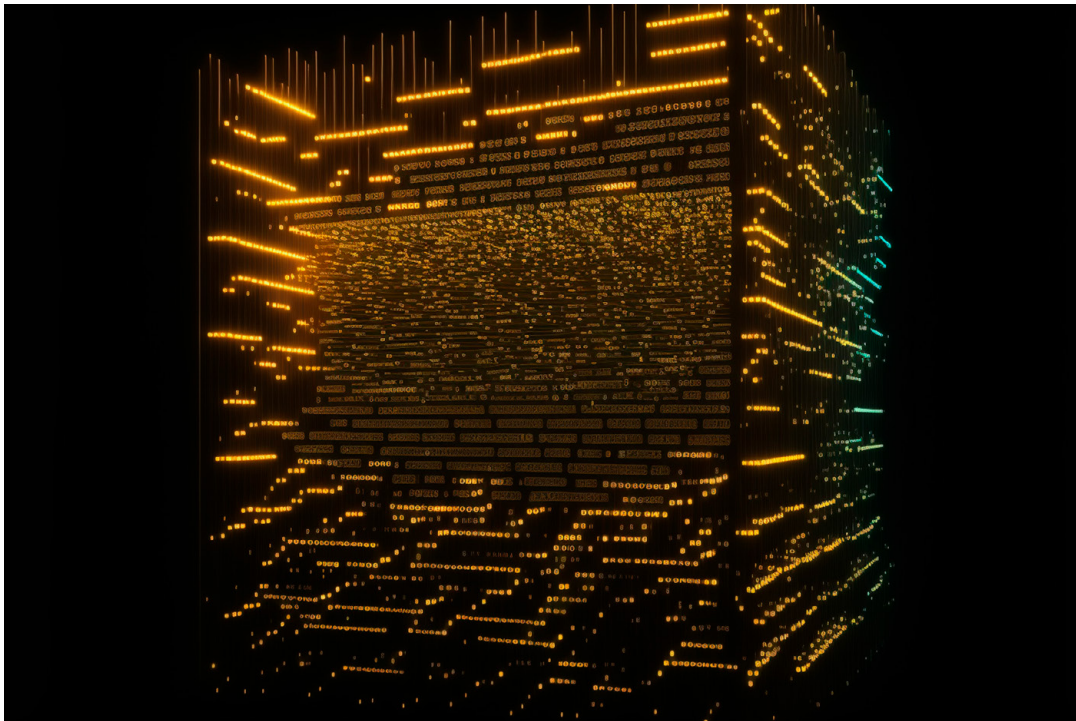
```

MonoBehaviour:
  m_ObjectHideFlags: 0
  m_CorrespondingSourceObject: {fileID: 0}
  m_PrefabInstance: {fileID: 0}
  m_PrefabAsset: {fileID: 0}
  m_GameObject: {fileID: 0}
  m_Enabled: 1
  m_EditorHideFlags: 0
  m_Script: {fileID: 11500000, guid: a2d85be56c1ae45d69604547c4544ba5,
  m_Name: PlayerID
  m_EditorClassIdentifier:

```

A ScriptableObject reduces overhead for storing data.

The ScriptableObject slims down this memory footprint and drops the GameObject and Transform which can have a significance at large scale commercial projects. It also stores the data at the project level. That can be helpful, especially if you need to access the same data from multiple scenes.



The extra data from a MonoBehaviour might not impact your application's performance at first, but as your game grows to commercial scale, with many more objects, it will become noticeable.



## ScriptableObject data versus persistent data

When ScriptableObjects are referred to as data containers, this usually refers to static or shared configuration data that does not need to change at runtime in a permanent way.

While changes to ScriptableObject data do persist within the Editor (much like modifying a material or a prefab), these changes won't save at runtime in an application build. Any changes made to a ScriptableObject instance during gameplay exist only in memory and are lost when the session ends.

Persistent data that needs to be saved from one session and then loaded into another is typically stored in a different file format (e.g., JSON, XML, [MessagePack](#), [Protocol Buffers](#), and so on). See Dual Serialization below for more details.

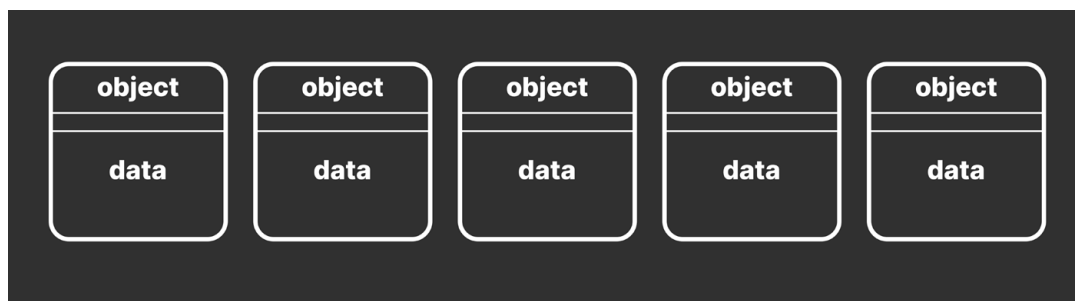
It's possible to change ScriptableObject data at runtime (e.g., ScriptableObject variables and Runtime Sets) in the game build, but these changes are temporary. Starting a new game session will revert the ScriptableObject data back to its original state at build time.

Think of ScriptableObject data as “read-only” for persistent data purposes. Persistent data should be “read-write” and stored externally.

## Reducing duplicate data

Imagine you have a thousand GameObjects with custom MonoBehaviours, each with several fields.

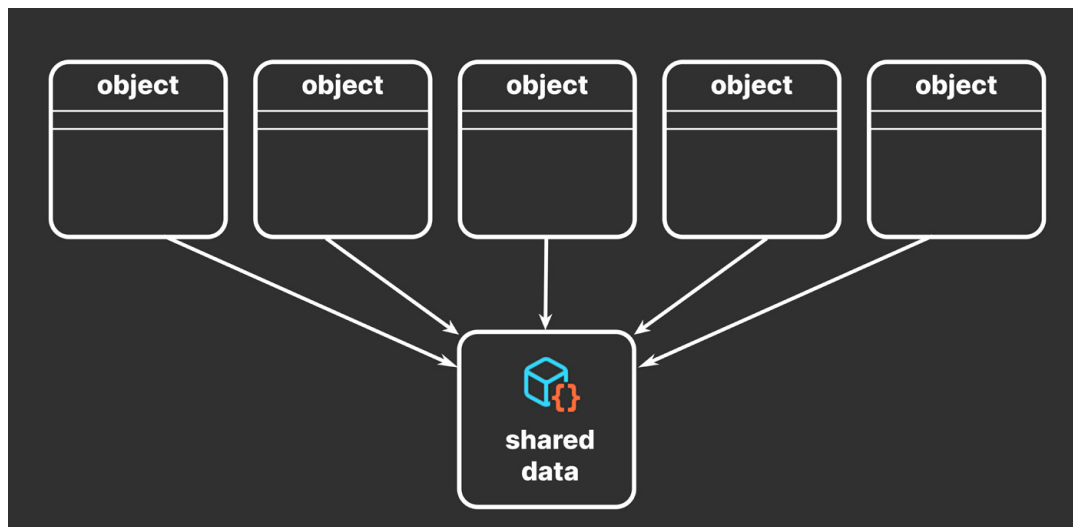
If each component holds its own copy of these values, you're duplicating a lot of data in memory. This is inefficient, especially when the data is identical across instances and doesn't change at runtime.



Many objects with duplicate, local data leads to performance inefficiencies.



Instead of duplicating this static data, you can funnel it into a ScriptableObject. Then, each of the thousand objects can point to this shared data asset. Each object stores a reference to the data rather than copying the data itself.



Many objects sharing data via a ScriptableObject

In software design, this is an optimization known as the [flyweight pattern](#). Restructuring your code in this way avoids copying a lot of values and reduces your memory footprint.

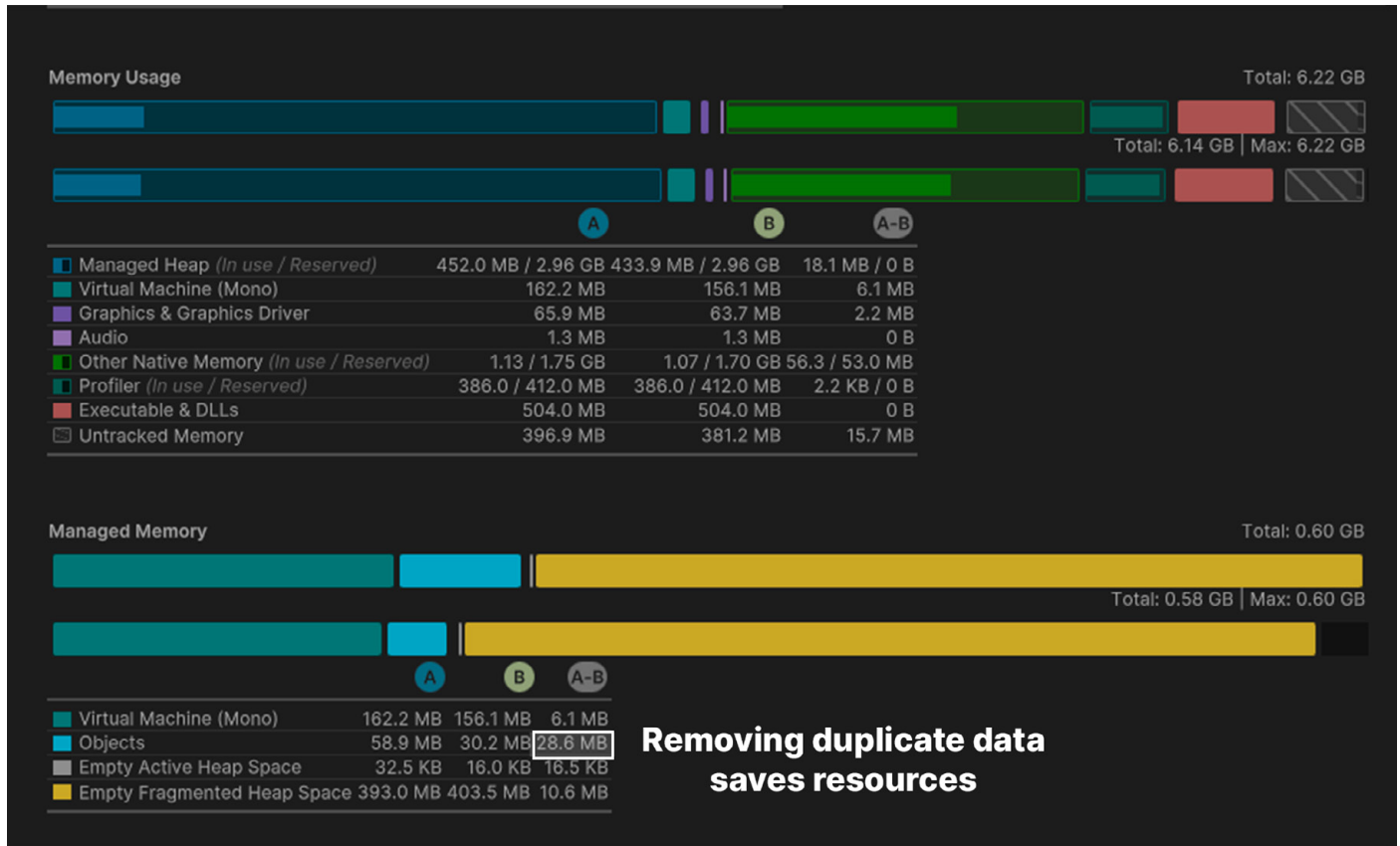


## Design patterns

Design patterns can help developers create more maintainable and flexible code, which can be useful in the often-changing world of game development.

Download the free e-book [Level up your code with design patterns and SOLID](#) for more about SOLID principles and design patterns.

A reference to the ScriptableObject (instead of a full copy of the data) is comparatively small. As you scale up, the memory savings from not duplicating data can become significant.



The Memory Profiler compares memory usage of duplicate (A) versus shared data (B).

You can store large quantities of shared data in this manner. Consider ScriptableObjects for:

- Saving and storing data during an Editor session
- Saving data as an Asset for use at runtime

Unlike MonoBehaviours, ScriptableObjects can't be attached to a GameObject. Instead, you save them as assets in your project. This is especially useful if you have a prefab that uses unchanging data in its MonoBehaviours.



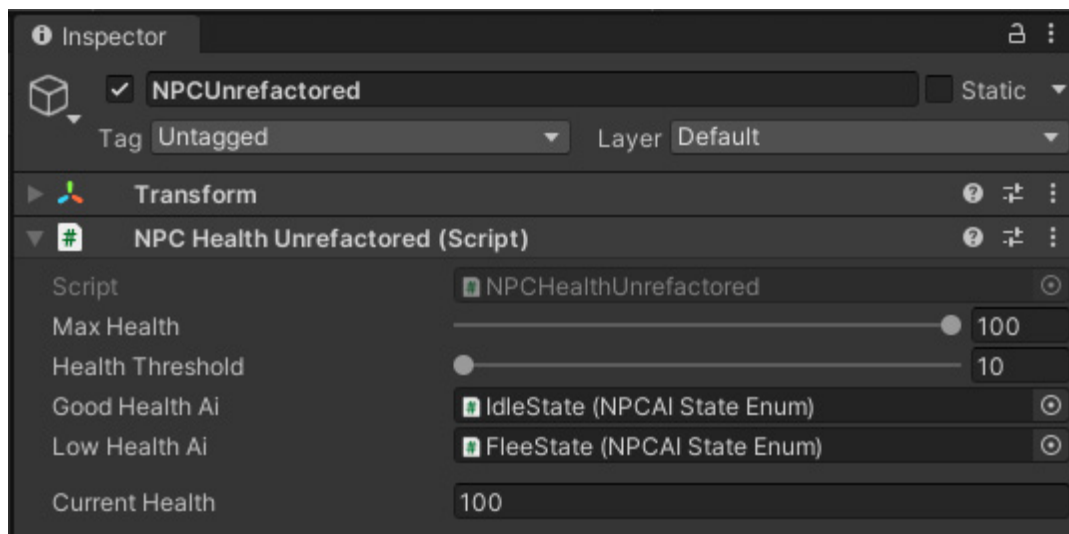
## Refactoring example

Consider a MonoBehaviour that controls an NPC's health. You might define its class like this:

```
public class NPCHealthUnrefactored : MonoBehaviour
{
    [Range(10, 100)]
    public int MaxHealth;
    [Range(10, 100)]
    public int HealthThreshold;

    public int CurrentHealth;
}
```

This works, but you have data that you won't expect to change at runtime. If you have many objects with NPCHealthUnrefactored attached, this can lead to a lot of unnecessarily duplicated data.



An NPCHealth MonoBehaviour before refactoring





Any data that does not need to change can move it into a ScriptableObject:

```
[CreateAssetMenu(fileName="NPCConfig")]
public class NPCConfigSO : ScriptableObject
{
    [Range(10, 100)]
    public int maxHealth;

    [Range(10, 100)]
    public int healthThreshold;
}
```

Use the `CreateAssetMenu` attribute to configure the menu action. You can optionally specify the default [fileName](#) or menu item [order](#).



### Code conventions in this guide

Many of the code samples in this guide are simplified for illustrative purposes and easier readability (e.g., public fields).

In production, use private fields and public [properties](#) for additional encapsulation and flexibility. Apply the [SerializeField](#) attribute to private fields to make them appear in the Editor's Inspector.

A naming convention can also help differentiate scripts for ScriptableObjects from MonoBehaviours. One way to achieve this is to add a "Data" or "SO" suffix at the end of the class name. While this isn't necessary, it can help keep your project organized and reduce ambiguity.

It's recommended that you maintain and follow a code style guide as your codebase grows. See [Create a C# style guide \(Unity 6 edition\)](#) for more information.

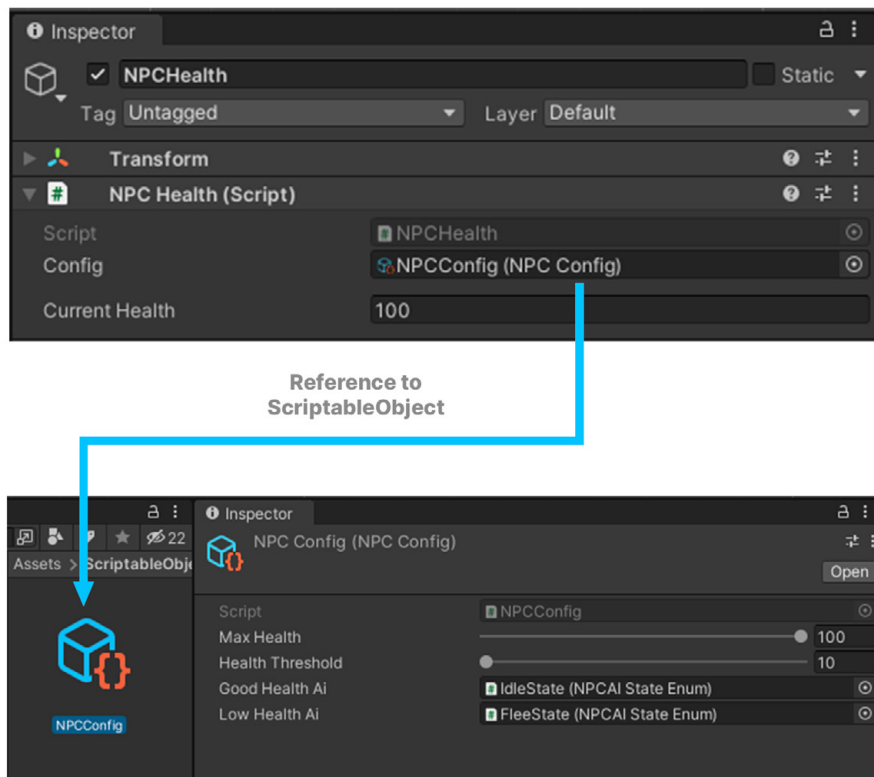
Then the refactored NPCHealth component simplifies to this:

```
public class NPCHealth: MonoBehaviour
{
    // Reference to our ScriptableObject
    public NPCConfigSO Config;

    public int CurrentHealth;
}
```



The MonoBehaviour now contains a reference to this new ScriptableObject. In the Inspector, everything after refactoring looks similar, except the data is split.

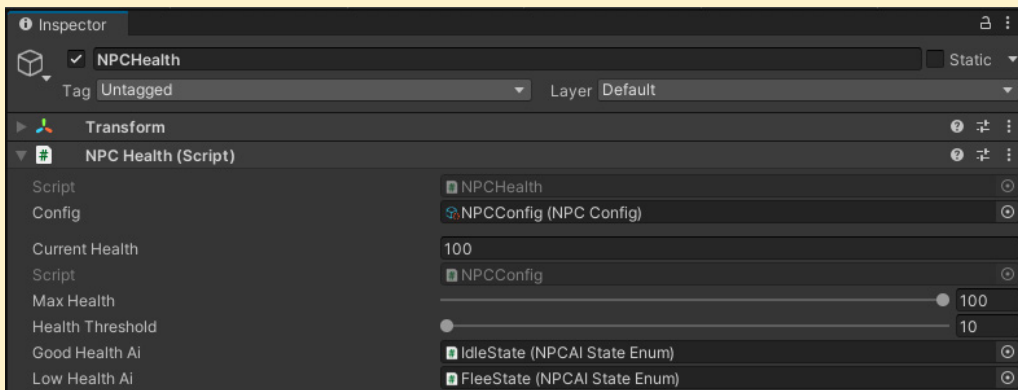


Refactoring splits data between a MonoBehaviour and ScriptableObject

## Custom Inspectors

When separating data into a ScriptableObject, you have data contained in two places, the ScriptableObject asset and the MonoBehaviour referencing it.

To make your MonoBehaviours easier to navigate, consider creating a custom editor. Below is an example for the NPCHealth.



A custom Inspector shows the ScriptableObject's variables in the MonoBehaviour.



This allows you to inspect the NPCConfig's variables alongside the other properties in the MonoBehaviour. If you select the original NPCHealth prefab, you can easily edit values in both objects.

A custom editor requires only a few lines of code:

- Derive a new class from `Editor`, and store this in a folder named "Editor." Apply the `CustomEditor` attribute with the `NPCHealth` type.
- Reserve a temporary editor for the `NPCConfig` `ScriptableObject`.
- In `OnInspectorGUI`, create the editor for the `NPCHealth` component.
- Draw the inspectors from the base class and new custom Inspector.

```
using UnityEditor;

[CustomEditor(typeof(NPCHealth))]
public class NPCHealthEditor : Editor
{
    private Editor editorInstance;

    private void OnEnable()
    {
        // Reset the editor instance
        editorInstance = null;
    }

    public override void OnInspectorGUI()
    {
        // The inspected target component
        NPCHealth npcHealth = (NPCHealth)target;

        if (editorInstance == null)
            editorInstance = Editor.CreateEditor(npcHealth.config);

        // Show the variables from the MonoBehaviour
        base.OnInspectorGUI();
    }
}
```



```
// Draw the ScriptableObjects inspector
editorInstance.DrawDefaultInspector();

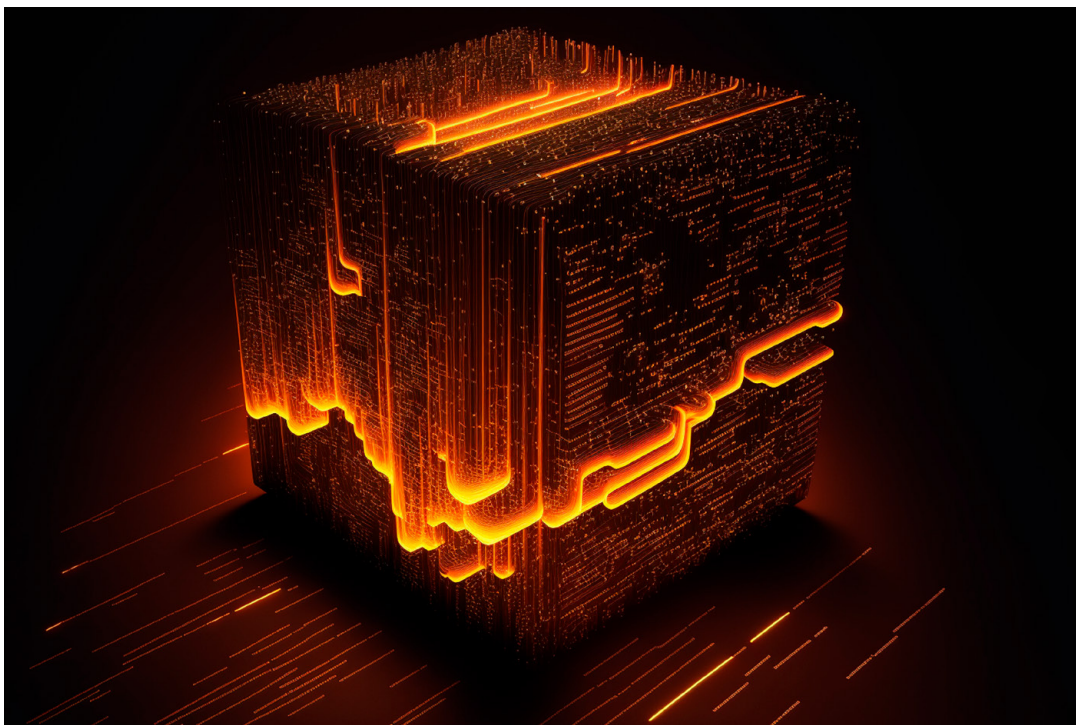
}

}
```

You can expand on this example with custom property drawers and editor attributes. This can even make for a better user experience when working with ScriptableObjects.

## Architectural benefits

With ScriptableObjects, you can cleanly separate shared and unshared data. Anything unique and dynamic to the GameObject instance remains inside the MonoBehaviour, while the shared data is stored in the ScriptableObject. Architecture with ScriptableObjects, however, goes beyond just saving memory.



There are a few benefits to restructuring the code architecture:

- **Designers can work more independently from software developers:** Storing data and logic on a single MonoBehaviour creates the potential for developers and game designers to step over each other's work. If two people change different parts of the same prefab or scene, this results in a time-wasting merge conflict. Breaking off shared data into smaller files and assets reduces these problems. Architecting with ScriptableObjects also enables designers to build gameplay without always relying on a programmer.



Just be prepared to define a clear workflow between your teams when sharing data. Good communication and establishing some boundaries can help prevent issues here. Some extra error checking or data validation may be necessary as well (e.g., use a `Range` attribute or `OnValidate` to prevent bad values).

- **Editing shared data is faster and less error-prone:** Changes to the shared data now happen all at once. If you need to modify a setting for your NPCs, for example, you could adjust it in just one location, and have it propagate the changes for every affected component in every scene.

This reduces any potential errors from mass editing a large number of individual `GameObjects` by hand. Offloading data into `ScriptableObjects` can also help with version control and prevent merge conflicts when teammates work on the same scene or prefab.

- **Save gameplay tweaks in Play mode:** Play mode in the Editor is an opportunity for designers to experiment with gameplay and settings. However, any modifications made to `MonoBehaviours` are lost when exiting Play mode because Unity discards the temporary copy of the scene.

Because the `ScriptableObjects` are assets, changes to their values are saved regardless of whether Unity is in Play mode. This can be useful if you want to make adjustments at runtime.

This can, however, also be a liability if you want to revert those changes. Just remember to rely on Unity Version Control or another version control system, so you can always restore your work if necessary. See the guide [Version control and project organization best practices \(Unity 6 edition\)](#) for more information.

- **Improve scene loading times:** When saving a scene or prefab, Unity serializes everything inside of them. That includes every `GameObject`, every component attached to those `GameObjects`, and every public field. Unity does this without checking for duplicate data.

Moving data to `ScriptableObjects` can reduce your scene and prefab sizes which can noticeably impact loading and saving.



## ScriptableObject variables

You can make your shared data containers even more granular with a ScriptableObject representing just one value. For instance, you could create a ScriptableObject class called `IntVariable` that holds one public field called `value`:

```
using UnityEngine;

[CreateAssetMenu(menuName = "Variables/Int", order = 1)]

public class IntVariableSO : ScriptableObject
{
    public int value;
}
```

Then, you could use the `IntVariable` in a `MonoBehaviour`. Structuring a `PlayerHealth` class would then look like this:

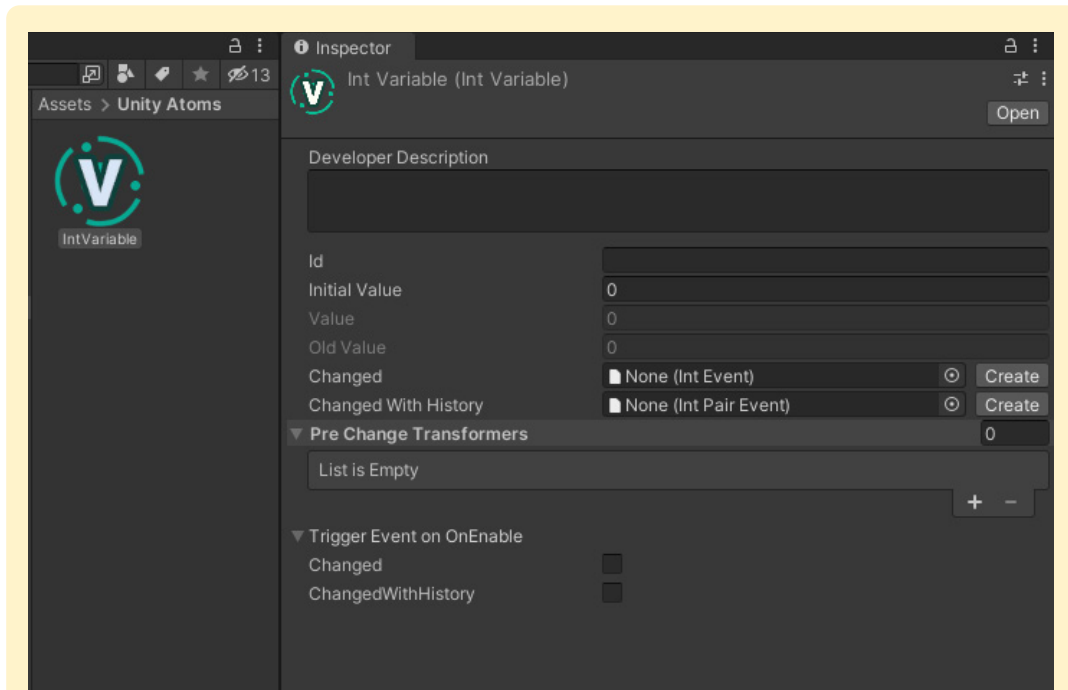
```
public class PlayerHealth : MonoBehaviour
{
    public IntVariableSO health;
}
```

Though we normally think of ScriptableObjects as holding unchanging values, you can give them methods that update this data at runtime (and reset to an initial value when exiting Play mode). In this way, you can make ScriptableObjects that essentially function as variables – containing integers, floats, booleans, and so on.

Your designers can then reserve data for game logic without needing a software developer each time they want to do it. However, this requires planning to be successful. Decide with your designers how to divide authoring gameplay data.

The key is to set some boundaries on how to collaborate. For example, the programming team might do the initial setup of ScriptableObjects for use with an inventory system. Then, the design team could use those to fill in each item's in-game stats or behaviors.

With some extra Editor scripting, this can become a near-seamless experience. Another possibility is making the fields in the Inspector toggle between using a shared value from a ScriptableObject and a constant. This can allow the game design team greater freedom to override the ScriptableObject data per instance.



Example of a ScriptableObject-based IntVariable from the open source Unity Atoms project

See the [Game architecture with ScriptableObjects](#) presentation from Unite Austin for how to implement this behavior in your own projects. You can also download the open source [Unity Atoms](#) project to see a working implementation of ScriptableObject variables.

## Dual serialization

You can mix how to serialize data within Unity. This allows you to work with ScriptableObjects in the Editor, but then store their data in another location, such as a JSON or XML file. This allows you to take advantage of each format's strengths.

File formats like JSON and XML are suitable for storing persistent data, such as save game data or settings, but can be difficult to work with in the Editor; however, they're easy to modify outside of Unity with any text editor.

In contrast, ScriptableObjects work well in the Editor and can be swapped with a quick drag-and-drop operation. However, they aren't easy to modify outside of Unity or share within your community of players.

Mixing serialized formats could open up new possibilities for your game, such as level editing or modding. At build time, a script can convert the other files into ScriptableObjects, which is faster to load than plain text.

While you'll want to keep some sensitive data safely tucked away on your servers (e.g., virtual currency, account information), exposing part of your game data to the community may enhance gameplay by allowing sandbox levels for user experimentation.



Imagine a ScriptableObject that defines your game level layout. It may simply contain a number of Transforms that define placement of prefabs, starting configurations, and so on. Your game scripts will use this data to assemble each level.

Imagine the walls and starting positions of a game, stored within a ScriptableObject:

```
[CreateAssetMenu(fileName = "LevelLayout")]
public class LevelLayout : ScriptableObject
{
    public Vector3[] wallPositions = new Vector3[2];
    public Vector3[] playerPositions = new Vector3[2];
    public Vector3[] goalPositions = new Vector3[2];
    public Vector3 ballPosition;
}
```

This defines how you set up the level. Your level management scripts can read the data from the LevelLayout object, then instantiate your prefabs in their correct positions.

A custom script can use JsonUtility to export this same data to disk. This results in a text file outside of the Editor that your users can modify with external tools.

To load a custom modded level, ScriptableObject.CreateInstance can generate a ScriptableObject at runtime. Then, read the text from the JSON file to populate the ScriptableObject. This LoadLevelFromJson example method shows that in action:

```
using System.IO;

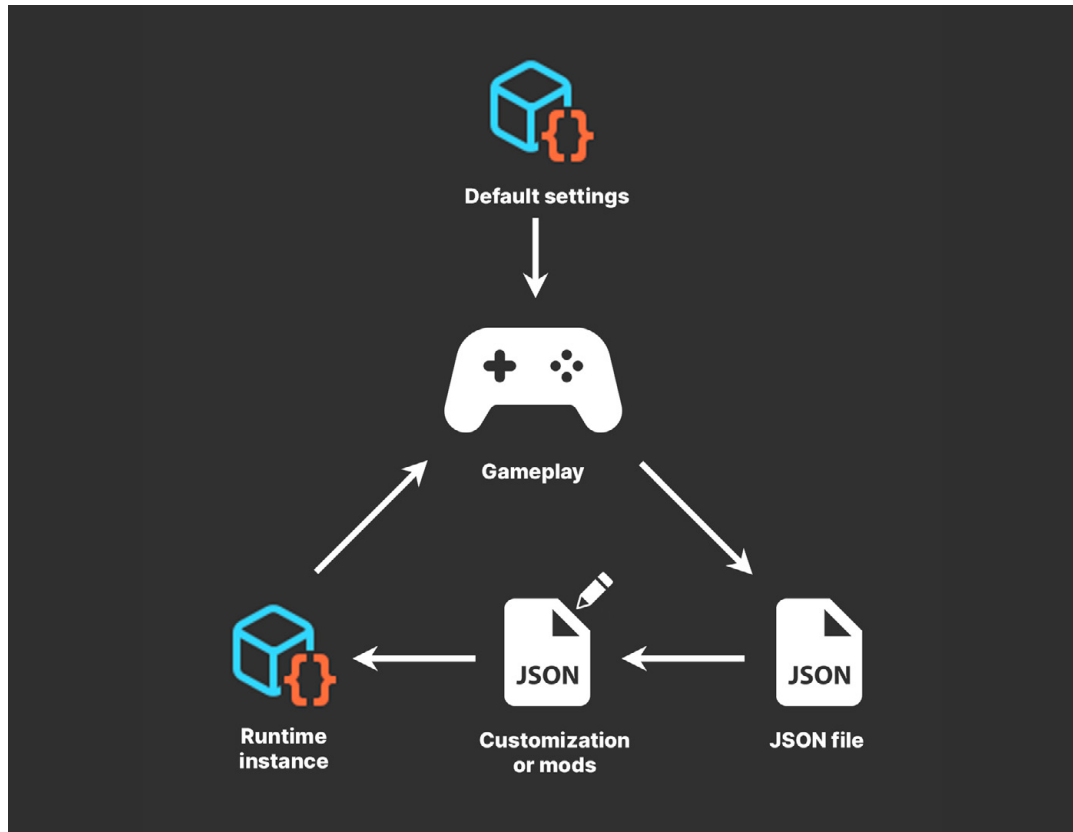
public class LevelManager : MonoBehaviour
{
    public ScriptableObject levelLayout;

    public void LoadLevelFromJson(string jsonFile)
    {
        if (levelLayout == null)
        {
            levelLayout = ScriptableObject.
                CreateInstance<LevelLayout>();
        }

        var importedFile = File.ReadAllText(jsonFile);
        JsonUtility.FromJsonOverwrite(importedFile, levelLayout);
    }
}
```

Your custom data replaces the contents of the ScriptableObject and allows you to use this externally modded level like any other in your game. The application is none the wiser.

Be sure to see this work for yourself in the [sample project](#). If we load a modified JSON file, this customized level overrides the default level data on the ScriptableObject.



Mix serialized formats for more flexibility

Note: When deserializing JSON into ScriptableObjects with JsonUtility, you must use the [FromJsonOverwrite](#) method.

Instead of creating a new object and loading the JSON data into it, JsonUtility loads the JSON data into an existing object. This updates the values stored in classes or objects without any allocations.





## Protect your data

The simple mod example described above demonstrates one possible application of ScriptableObjects. However, when exposing game data for modification, you should exercise caution to avoid players tampering with the rest of your application.

Here are common ways to protect anything that you don't want modded:

- **Encryption:** Use [encryption](#) to protect data files from being easily read or modified. This can make it more difficult for users to alter critical data.
- **Digital signatures:** You can use a [fingerprint algorithm](#) to verify that your data files have not been tampered with.
- **Server-side validation:** If your game relies on data that is stored on a server, check the data on the server before it is used in the game, and reject any data that appears to have been manipulated.

No single approach is foolproof, and it's generally a good idea to use a combination of these techniques so your players don't introduce any bugs or vulnerabilities into your game.

# The Extendable enums pattern

Game development often requires the task of solving recurring or similar problems. Fortunately, you can tap into the collective knowledge of software engineers who've already "been there and done that" with [design patterns](#).

Design patterns are general solutions that can help you build larger, scalable applications. They can improve code readability and make your codebase cleaner. Design patterns reduce refactoring and the time spent testing.

Think of a design pattern as template for solving common issues like:

- Storing a lot of data efficiently
- Getting objects from different game systems to speak to each other
- Swapping out behavior on the fly at runtime

ScriptableObjects can help implement some of these patterns. You've already seen how they can function as data containers, but they can do more than simply save values or settings. The next few sections explore how you can go beyond using ScriptableObjects to save data.

## Enum-like categories

In fact, ScriptableObjects actually don't have to contain anything at all to be useful. If you create an empty ScriptableObject, you'll discover that it still has utility, even if it's only used for comparing against other ScriptableObjects.

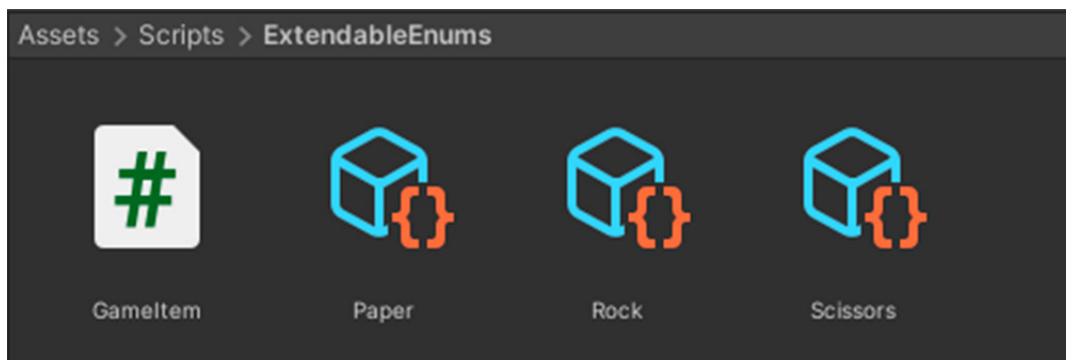


In your game application, suppose you make a number of assets from an empty `GameItemSO` `ScriptableObject`, like so:

```
Using UnityEngine;

[CreateAssetMenu(fileName="GameItem")]
public class GameItemSO : ScriptableObject
{
}

```



Empty `ScriptableObject`s work as enums.

This allows you to generate any number of assets within the project. Even without containing any data, the `ScriptableObject` itself can represent a category or item type, similar to an enum.

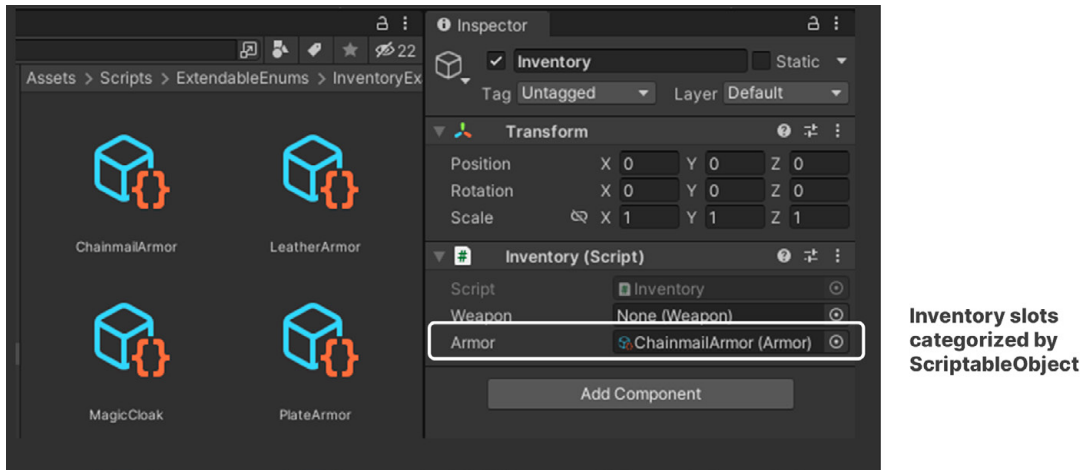
Do two variables refer to the same `ScriptableObject`? Then they're the same item type. Otherwise, they're not.

So, you could have a `ScriptableObject` that defines special damage effects (e.g., cold, heat, electrical, magic, and so on) or rock-paper-scissors designations from your favorite [zero-sum game](#).



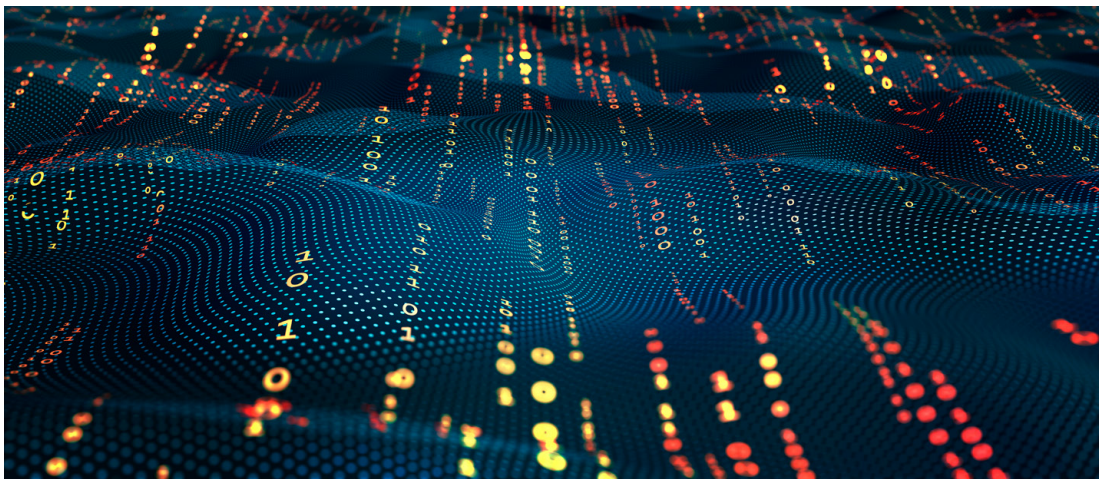
Comparing `ScriptableObject`s

If your application requires an inventory system to equip gameplay items, ScriptableObjects can represent item types or weapon slots. The fields in the Inspector then function as a drag-and-drop interface for setting them up.



Drag and drop ScriptableObject-based categories

This artist-friendly UI allows your designers how to modify and extend gameplay data without extra support from a developer. Giving the design team the means and responsibility of maintaining gameplay data allows everyone to focus on what they do best.



## Extending behavior

Using ScriptableObjects as enums becomes more interesting when you want to extend them by adding more data. Unlike normal enums, ScriptableObjects can have extra fields and methods.

Here's the adapted rock-paper-scissors GameItem. The ScriptableObject asset itself still defines the enum-like category, but this time it's no longer empty.



```
public class GameItem : ScriptableObject
{
    public GameItem weakness;
    public bool IsWinner(GameItem other)
    {
        return other.weakness == this;
    }
}
```

The ScriptableObject now contains a weakness field that determines which other item wins in a potential interaction. In addition to storing data, each ScriptableObject also contains simple comparison logic in IsWinner.

Each gameplay item then needs a MonoBehaviour that references a specific ScriptableObject asset. This example works as a controller script:

```
public class GameItemController : MonoBehaviour
{
    // rock, paper, scissors
    public GameItem gameItem;

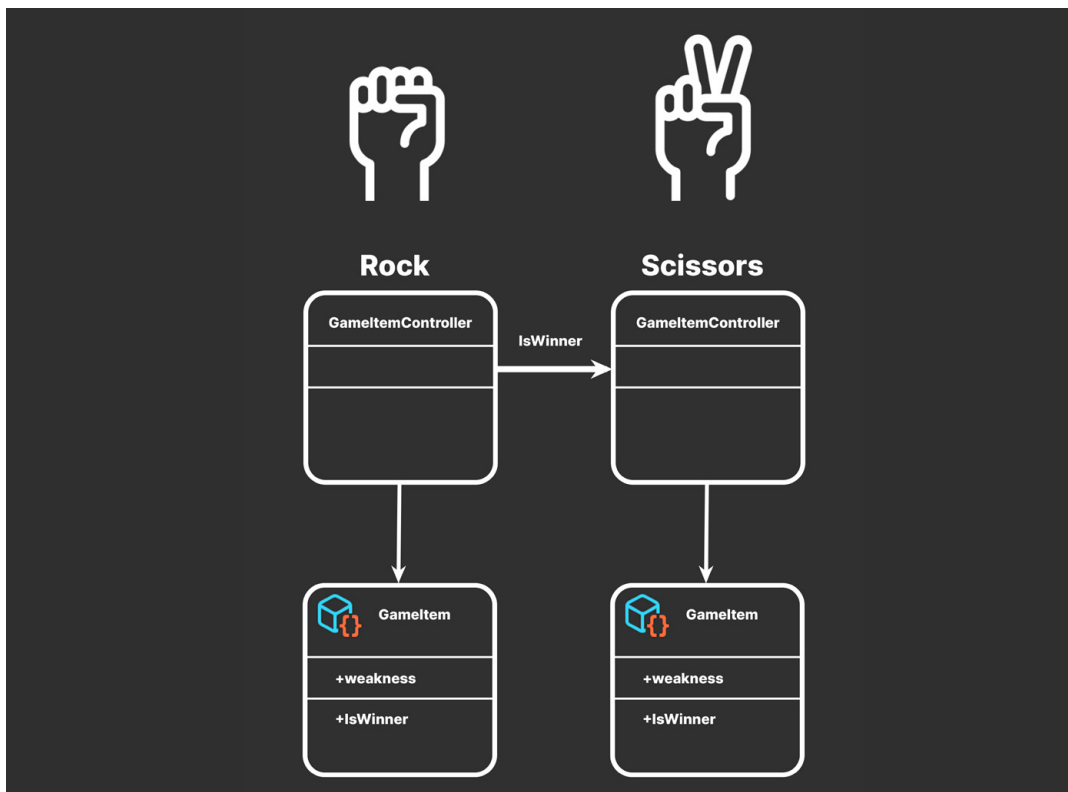
    private void OnTriggerEnter(Collider other)
    {
        GameItemController otherController = other.GetComponent<GameItem
Controller>();
        GameItem otherGameItem = otherController.gameItem;

        if (gameItem.IsWinner(otherGameItem))
        {
            Debug.Log(gameItem.name + " beats " + otherGameItem.name);
        }
    }
}
```



It references a `ScriptableObject` as a field. In `OnTriggerEnter`, you can check the `IsWinner` method to see which emerges victorious when the `gameItem` comes in contact with another. This sets the stage for some [Rochambeau-like conflict](#).

Unlike enums, `ScriptableObject`s are easy to extend. There's no need to have a separate lookup table or to correlate with a new array of data. Simply add an extra field and/or method to handle the logic.



ScriptableObjects with comparison logic  
Source: [Flatticon](#)

Compare that with maintaining a traditional enum. If you have a long list of enum values without explicit numbering, inserting or removing an enum can change their order. This reordering can introduce subtle bugs or unintended behavior.

`ScriptableObject`-based enums have no such issues. Add more to your project (or delete existing ones), and everything just works.

Suppose you wanted to make the item equippable in an RPG. You could append an extra boolean field to the `ScriptableObject` to do that. Are certain characters not allowed to hold certain items? Are some items magical or have special abilities? `ScriptableObject`-based enums can do that.

Your gameplay data can thus evolve as you work to implement the game design. While you'll need to coordinate how to set up fields initially, later the designers can fill out the details independently.

# Pattern: Delegate objects

ScriptableObjects in Unity aren't just for storing data; you can also put methods in them, meaning they can hold both what to do (logic) and what to use (data).



## Delegates versus events

Delegates and events are closely related concepts in C#, but they serve different purposes. A delegate is a type that defines a method signature. This allows you to pass methods as arguments to other methods. Think of it like a variable that holds a reference to a method, instead of a value.

An event, on the other hand, is essentially a special type of delegate that allows classes to communicate with each other in a loosely coupled way. Events are explored in more detail in the Pattern: Observer chapter.

For general information about the differences between delegates and events, see [Distinguishing Delegates and Events in C#](#).

The idea is that if you need to perform specific tasks, you encapsulate the algorithms for doing those tasks into their own objects. The original [Gang of Four](#) refers to this general design as the [strategy pattern](#).

Suppose you want a pathfinding object that calculates a route through a maze. The object itself wouldn't actually contain any pathfinding logic. Instead, it just keeps a reference to another object that does.





If you want to solve the maze with a specific [path search technique](#) (e.g., A\*, Dijkstra, etc.), implement the correct solution within this separate “strategy” object. At runtime, you can then swap to a different algorithm by exchanging objects.



## ScriptableObjects methods

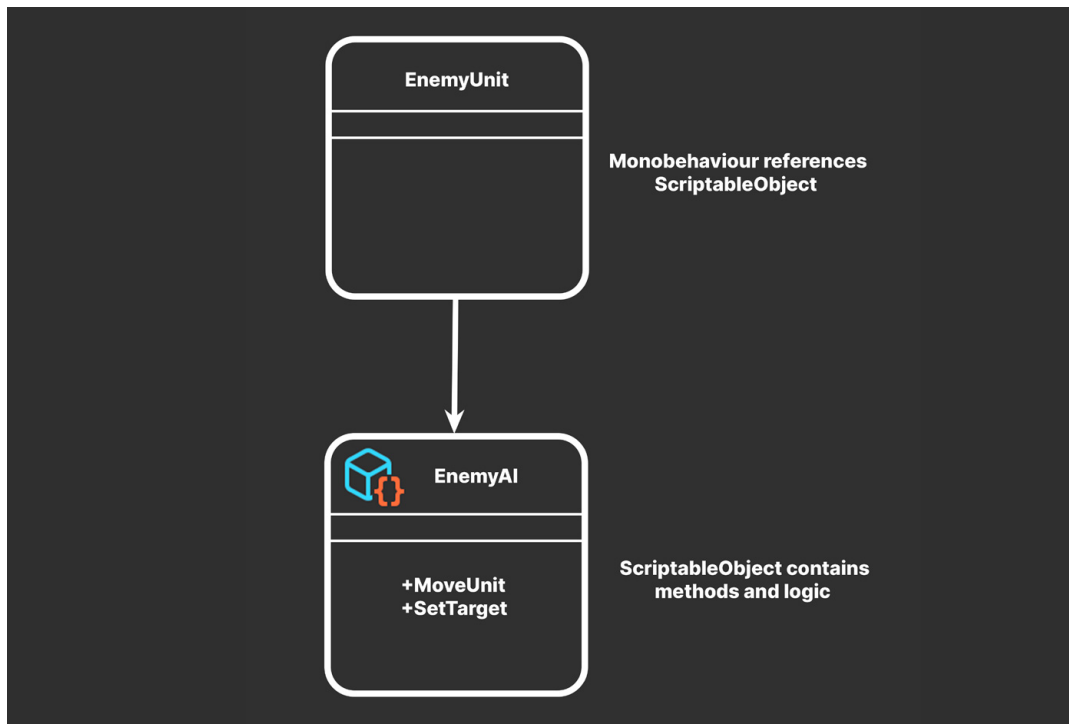
In Unity, one way to implement this pattern is to have a `MonoBehaviour` reference a `ScriptableObject` containing the necessary logic. When the `MonoBehaviour` performs a task, it calls the external methods on the `ScriptableObject` rather than its own.

However, there are a few limitations to this:

- Methods on a `ScriptableObject` won't be called automatically from the `MonoBehaviour`'s player loop (like `Start()`, `Update()`, and `OnCollisionEnter()`). You need to call them yourself.
- Like prefabs, `ScriptableObjects` can't reference scene objects directly. If they need to perform work on a scene object, you'll need to pass that object in as a parameter.

When calling the `ScriptableObject`'s methods, a `MonoBehaviour` can often pass in itself as the argument or pass in any other dependencies. This gives you the flexibility to execute logic, run coroutines, etc. even though the `ScriptableObject` exists at the project level.





ScriptableObjects can contain pluggable implementations of behavior or logic.

For example, you can define several enemy units in a game with different movement behavior. Let's suppose some of them need to patrol, stand idle, or flee from the player.

A single **EnemyUnit** MonoBehaviour can reference a **EnemyAI** ScriptableObject that contains a method called **MoveUnit**. The **EnemyUnit** script itself doesn't contain any movement or behavior logic. It only executes the ScriptableObject's **MoveUnit** at the appropriate time.

If the method needs data from the scene, the **EnemyUnit** object can pass in a reference to itself as a parameter. Any other necessary dependencies in the scene can be passed in as well.



### Modifying ScriptableObject data

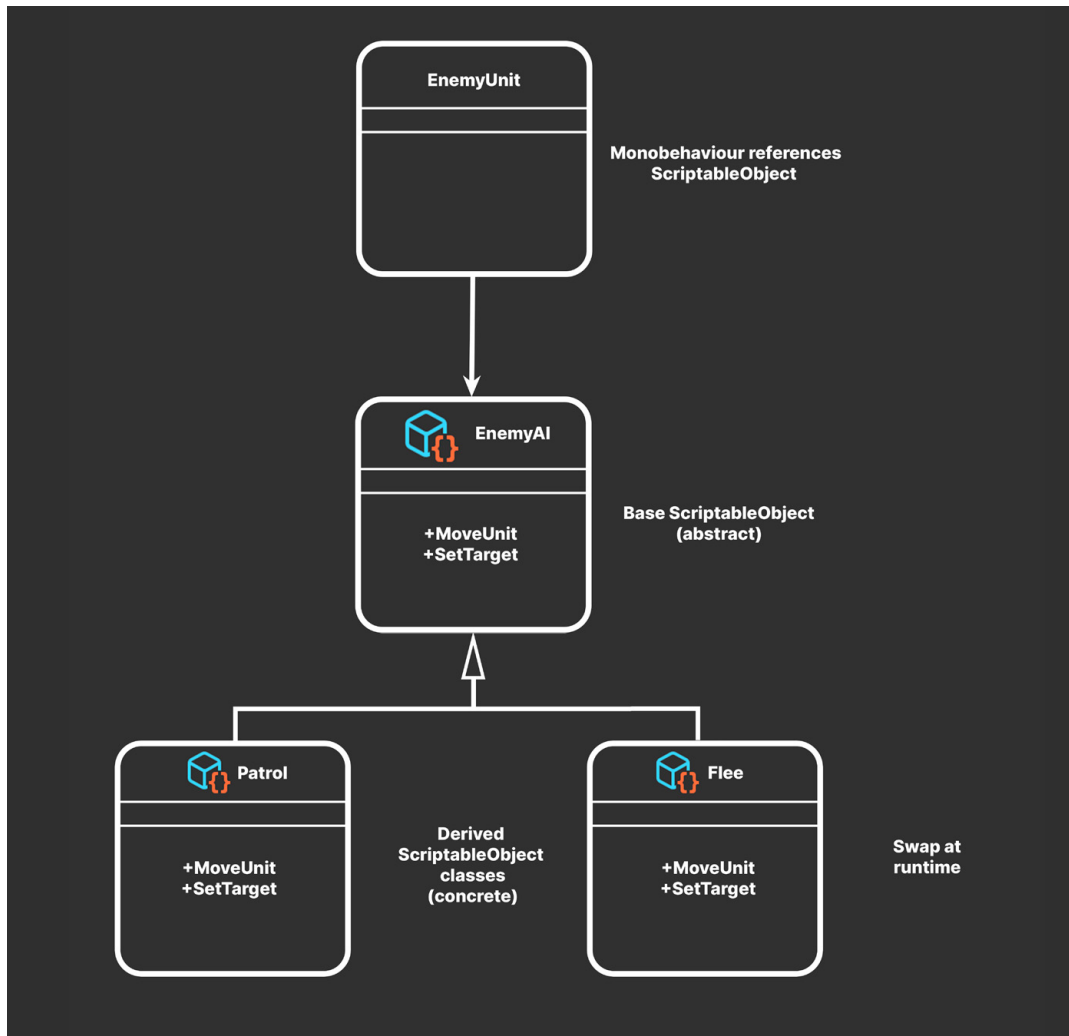
At runtime, you actually can change ScriptableObject data, but be careful whenever doing so. Multiple MonoBehaviour sharing the same ScriptableObject can cause problems if they modify the same data.

Remember that you can create an *instance* of a ScriptableObject at runtime to avoid this issue. The initial ScriptableObject then acts like a template with all the logic and data. Each MonoBehaviour can then make its own instance of that ScriptableObject which can be modified freely.



## Pluggable behavior

You can make this pattern more useful by defining the EnemyAI ScriptableObject as an abstract class. This allows it to act as a template for a variety of ScriptableObjects that are compatible with the EnemyUnit MonoBehaviour, so the abstract ScriptableObject can stand in for more than one algorithm.



Pluggable behaviors can change at runtime or in the Editor.

Thus, you could have concrete ScriptableObject classes for behaviors like **Patrol**, **Idle**, or **Flee** that derive from the base **EnemyAI**. Even though they all implement the same **MoveUnit** method, each can produce very different results.

In the Editor, each asset is interchangeable. You can just drag and drop the ScriptableObject of choice into the **EnemyAI** field. Any compatible ScriptableObject is “pluggable” in this fashion.



The EnemyUnit or another component can behave as the “brain” that monitors when to switch ScriptableObjects and also swap behavior at runtime. This is one way the EnemyUnit can react to gameplay events like transitioning from a patrolling to a fleeing state. Simply switch EnemyAI ScriptableObjects on each state change.

In production, a second developer or designer can implement the actual movement or AI logic within the ScriptableObject. As additional movements or behaviors get added to the game (e.g., DuckAndCover, Chase, etc.), the original EnemyUnit script remains unchanged. This pattern can help keep your codebase more extensible, in keeping with the [open-closed principle](#) from [SOLID](#) programming. Because everything is already split into smaller objects, the resulting project is more scalable as you add team members or as game design changes.



## Gameplay AI with ScriptableObjects

For a more detailed example of using ScriptableObjects to drive behavior, see the [Pluggable AI With Scriptable Objects](#) video series. These recorded live sessions demonstrate a finite state machine-based AI system that can be configured using ScriptableObjects for states, actions, and transitions between those states.

## Example: Audio delegates

The behavior contained in the ScriptableObject does not necessarily need to be complex. It can be something as basic as playing back a customized sound.

Here's an example of a “sound delegate” ScriptableObject that can help add variations to your AudioClips. The AudioDelegateSO defines an abstract class with a Play method that takes an AudioSource as a parameter.

```
using UnityEngine;
using Random = UnityEngine.Random;
using System;

[Serializable]
public struct RangedFloat
{
    public float MinValue;
    public float MaxValue;
}

public abstract class AudioDelegateSO: ScriptableObject
{
    public abstract void Play(AudioSource source);
}
```



This concrete SimpleAudioDelegate ScriptableObject can then select a random clip from the available choices and vary its volume and pitch during playback. This reduces the monotony of repeating the same sound.

```
[CreateAssetMenu(fileName = "AudioDelegate")]
public class SimpleAudioDelegateSO : AudioDelegateSO
{
    public AudioClip[] Clips;
    public RangedFloat Volume;
    public RangedFloat Pitch;

    public void Play(AudioSource source)
    {
        if (clips.Length == 0 || source == null)
            return;

        source.clip = clips[Random.Range(0, Clips.Length)];
        source.volume = Random.Range(Volume.minValue, Volume.maxValue);
        source.pitch = Random.Range(Pitch.minValue, Pitch.maxValue);
        source.Play();
    }
}
```

Any MonoBehaviour can then use a ScriptableObject instance derived from the AudioDelegateSO class. You can also make variations of the AudioDelegate for different audio effects.

Having methods on a ScriptableObject opens up several possibilities. In addition to performing actions, its methods can send messages to any object in the scene.

Next, let's look at a ScriptableObject-based event system with the observer pattern.



## The glorious ScriptableObject revolution

Richard Fine's [Overthrowing the MonoBehaviour tyranny in a glorious ScriptableObject revolution](#) presentation at Unite 2016 lay the foundation for much of this e-book. Part of the demo (called AudioEvent in the original project) has been modified for this example.

See the [sample project](#) for implementation details and an example using ScriptableObjects.

# The Observer pattern

When developing a game, it's common to have multiple `GameObjects` that need to share data or states with each other. In a small game, you can make direct references between these objects, but this doesn't scale very well. Managing these dependencies can require significant effort and is often a source of bugs.

You'll need a better solution as your application grows in size.

## Avoiding singletons

Many developers opt to use singletons – one global instance of a class that survives scene loading. Singletons, however, introduce global states and make unit testing difficult.

If you're working with a prefab that references a singleton, you'll end up importing all of its dependencies just to test an isolated function. This reduces modularity and makes your code harder to debug.

As an alternate solution you can use `ScriptableObject`-based events to help your objects communicate.



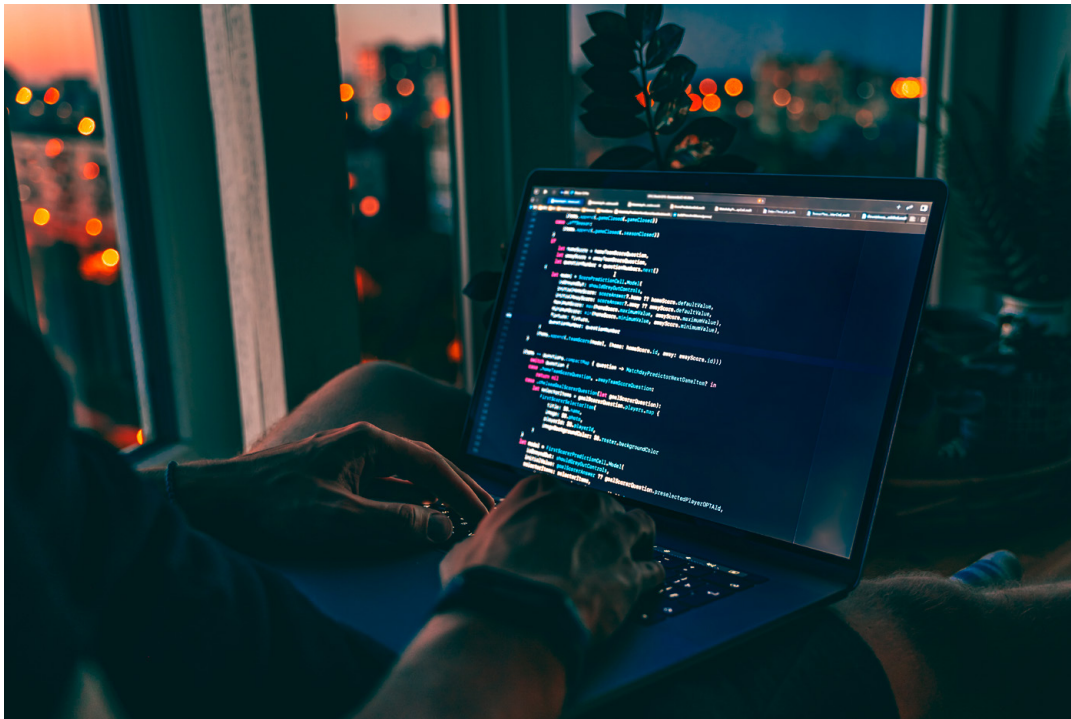
## More on singletons

The subject of singletons in Unity game development is often cause for debate. Singletons can be a suitable solution for smaller projects or prototyping. In large applications, the cons of using singletons often outweigh their advantages. Many developers consider the singleton to be an anti-pattern for this reason.

Singletons are easy to learn and understand but can introduce issues when they're used incorrectly. Most of the patterns described here will help you avoid relying on singletons.

If you want easy access to shared data, consider a Runtime Set based on ScriptableObjects (see below). If you need a way to send messages between objects, try a ScriptableObject-based event channel. Restructuring your architecture away from singletons may improve scalability and testability.

Read the e-book [Level up your code with design patterns and SOLID](#) to learn more about the pros and cons of singletons.



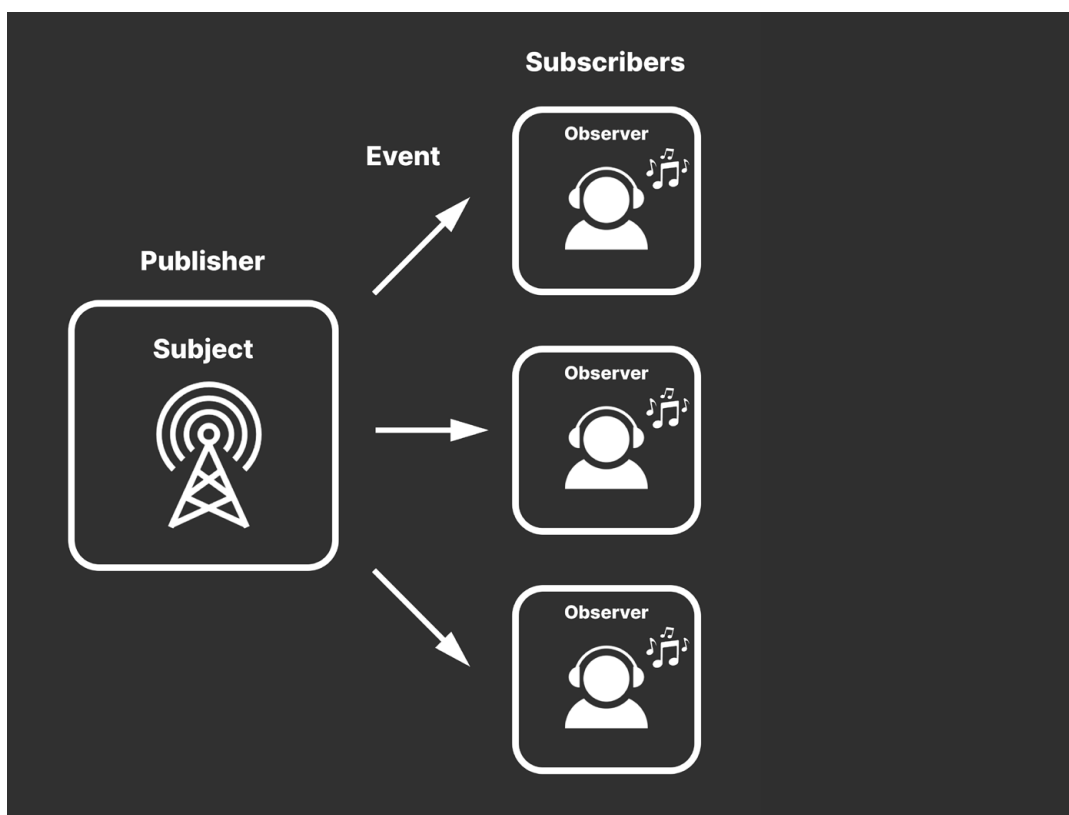


## ScriptableObject-based events

As you've already seen, ScriptableObjects aren't just for handling data. They can contain methods, just like any other script. These methods can serve as a means for objects to communicate.

In the [observer design pattern](#), a subject broadcasts a message to one or more loosely coupled observers. Each observing object can react independently of the subject but is unaware of the other observers. The subject can also be referred to as the "publisher" or "broadcaster." The observers are also known as "subscribers" or "listeners."

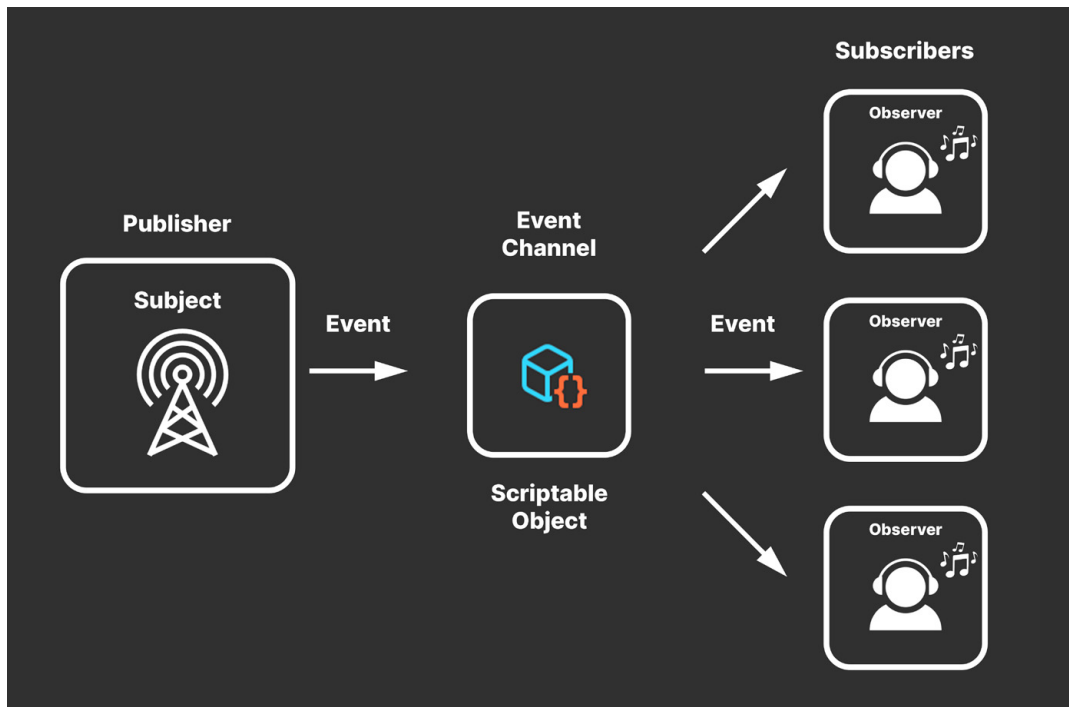
An event-based architecture only executes when needed, rather than running each frame. For this reason, it's often more optimized than adding logic to a MonoBehaviour's update methods.



The basic observer pattern

You can implement the observer pattern with MonoBehaviours or [C# objects](#). While this is already common practice in Unity development, a script-only approach means your designers will rely on the programming team for every event needed during gameplay.

An alternative is to create ScriptableObject-based events. This is a designer-friendly way to set up the observer pattern. Here, the ScriptableObject works as an intermediary between subject and observer, providing a graphical interface in the Editor.



The ScriptableObject-based event channel

While at first glance it appears that you’ve only added a layer of overhead to the observer pattern, this structure offers some advantages. Because ScriptableObjects are assets, they are accessible to all objects in your Scene Hierarchy and don’t disappear on scene loading.

This is why many developers use singletons in the first place: easy, persistent access to certain resources. ScriptableObjects can often provide the same benefits without introducing as many unnecessary dependencies.

In ScriptableObject-based events, any object can serve as publisher (which broadcasts the event), and any object can serve as a subscriber (which listens for the event). The ScriptableObject sits in the middle and helps relay the signal, acting like a centralized intermediary between the two.

One way to think about this is as an “event channel.” Imagine the ScriptableObject as a radio tower that has any number of objects listening for its signals. An interested MonoBehaviour can simply subscribe to the event channel and respond when something happens.





## Example: Event channels

Any `ScriptableObject` that includes the following can function as an event channel:

- **A delegate (`UnityAction` or `System.Action`):** This notifies subscribers and passes the appropriate data as parameters. Use a `UnityAction` for a more artist-friendly experience; otherwise, the `System.Action` delegate works well here.

The event keyword limits the delegate so that it can only be invoked from within the `ScriptableObject` class (or derived class where it's declared).

- **An event-raising method:** This public method invokes the delegate.

And that's it.

You can set up any number of event channels to determine various aspects of gameplay. Because they exist at the project level, `ScriptableObjects` can raise events that are globally accessible. This can connect otherwise unrelated objects in the scene in a scalable way.

### System.Action or UnityAction

`System.Action` is a general purpose delegate type defined in the .NET Framework's `System` namespace. It can be used in your Unity projects without needing to declare a custom delegate. Adding the event keyword makes the delegate type read only; other objects can listen for the delegate's registered methods, but they can't invoke those methods directly.

`UnityAction` is a delegate type that's specifically defined within the `UnityEngine.Events` namespace. You will typically use it with the `UnityEvent` class, which is an alternative means of creating events in Unity. `UnityEvents` and `UnityActions` appear in the Inspector, so they often serve as a more user- or artist-friendly way to implement the observer pattern.

In general, you can use either `System.Action` or `UnityAction`, depending on your specific needs. You have the option of deploying either or both in the same project.

If you want a more general purpose delegate that is not tied to the Unity game engine, use `System.Action`. If you want a delegate specifically designed for `UnityEvents`, use `UnityAction`.

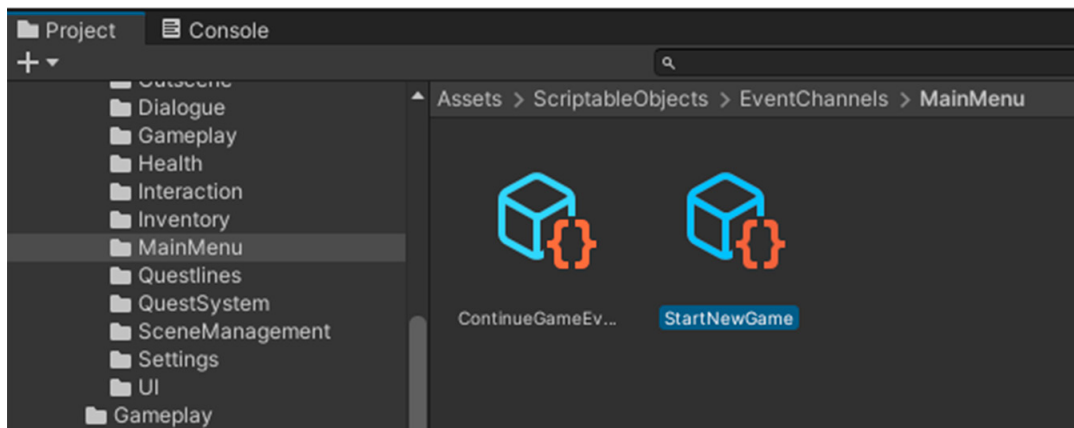


Here, you can make a `VoidEventChannelSO` that raises an event without passing any parameters. This one contains a `UnityAction` named `OnEventRaised`.

```
[CreateAssetMenu(menuName = "Events/Void Event Channel")]
public class VoidEventChannelSO : ScriptableObject
{
    public event UnityAction OnEventRaised;
    public void RaiseEvent()
    {
        if (OnEventRaised != null)
            OnEventRaised.Invoke();
    }
}
```

Once you create a `ScriptableObject` of type `VoidEventChannelSO`, any `MonoBehaviour` can listen for `OnEventRaised`. For example, we can make a `StartNewGame` `ScriptableObject` that is of type `VoidEventChannelSO`.

Another object can invoke the public `RaiseEvent` method to trigger the event.



A `ScriptableObject`-based event, an example of an event channel

Another `MonoBehaviour` can reference the event channel `ScriptableObject` in the Inspector, then subscribe/unsubscribe to `OnEventRaised`.



This invokes `StartNewGame` as a response whenever the event channel calls `OnEventRaised`:

```
public class StartGame : MonoBehaviour
{
    [SerializeField] private VoidEventChannelSO m_onNewGameButton =
    default;

    private void Start()
    {
        m_onNewGameButton.OnEventRaised += StartNewGame;
    }

    private void OnDestroy()
    {
        m_onNewGameButton.OnEventRaised -= StartNewGame;
    }

    private void StartNewGame()
    {
        // load level logic here...
    }
}
```

For more artist- or designer-friendly listening components, you could instead create a `MonoBehaviour` that doesn't require any script setup. This `VoidEventListener` class doesn't add extra functionality but has fields that are accessible in the Inspector:

```
public class VoidEventListener : MonoBehaviour
{
    [SerializeField] private VoidEventChannelSO m_channel = default;

    public UnityEvent OnEventRaised;

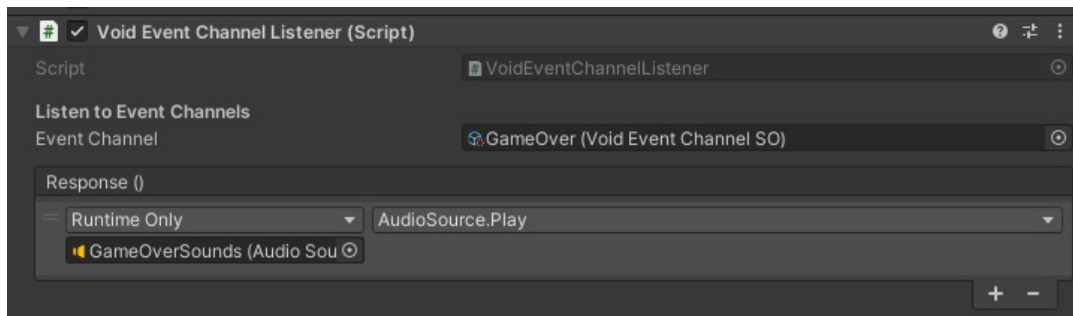
    private void OnEnable()
    {
        if (m_channel != null)
            m_channel.OnEventRaised += Respond;
    }
}
```



```
private void OnDisable()
{
    if (m_channel != null)
        m_channel.OnEventRaised -= Respond;
}

private void Respond()
{
    if (OnEventRaised != null)
        OnEventRaised.Invoke();
}
}
```

Simply add the `VoidEventListener` to a `GameObject`, then drag the event channel `ScriptableObject` into the `_channel` field in the Inspector. Create `UnityActions` on the `OnRaisedEvent` in order to respond to the event.



An Event Listener allows a nonprogrammer to set up event-driven actions.

Regardless of which component you choose to listen for events, the event channels provide a means of communicating between your objects at runtime. Did the player complete a task or score a point? Is the game over? An event can notify any `GameObject` in the scene that needs that information.

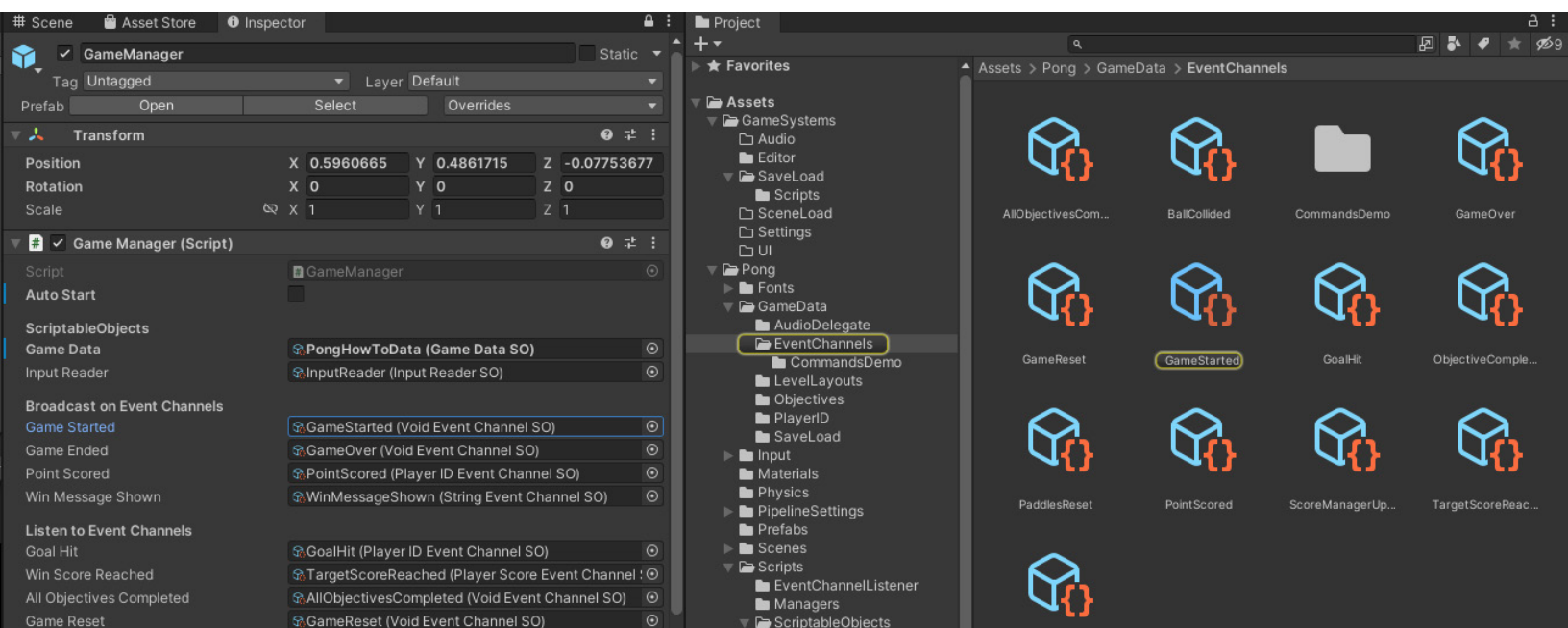
Because they are assets at the project level, `ScriptableObject`-based events can then drive much of the infrastructure of your application. This is especially useful for sending messages between the different systems that underpin the game architecture.

Some common management systems include:

- **Audio management:** Many things in your game can trigger sounds. This system can play AudioClips or adjust the AudioManager in response to application events.
- **Scene management:** This system handles loading and unloading of Unity scenes and game levels.
- **UI management:** This is responsible for menu screens before, during, and/or after gameplay.
- **Save Data management:** This handles saving and loading game data, as well as settings to your file system.

These systems all specialize in different tasks, but they need to talk to one another. Events can form the glue that keeps them connected.

Explore the accompanying [sample project](#) for more examples of how to implement your own ScriptableObject-based events.



The sample project's GameManager uses event channels.

Note that you can send different types of data with each event, using different event payloads. For example, the ScriptableObject-based events include `IntEventChannelSO`, a `Vector2EventChannelSO`, a `VoidEventChannelSO`, and so on. The event used will depend on the context.

Customize additional event types according to gameplay. For instance, a damage event may need to pass along who inflicted the damage and how much was done.



How you deploy these event channels is limited only by your creativity. In addition to the core systems above, events can often help join very different in-game systems so that they can interact:

- **Cameras:** These are used to add dramatic or cinematic effects, such as shaking or cutting to a different perspective.
- **Quests:** These are tasks or objectives that the player must complete in order to progress through the game or receive a reward. Quests often involve a variety of gameplay elements, such as fetching items, defeating enemies, or solving puzzles.
- **Health:** This important aspect of many games connects the player, enemies, and any objects or actions that can cause damage to the player.
- **Achievements:** Like quests, these are special rewards that players can unlock by completing certain tasks or objectives within the game. Achievements can span different gameplay elements, such as reaching a certain level or accumulating a certain number of points.

These gameplay elements, in turn, will interact with other management systems, such as audio, UI, and save data, through the use of events. This approach promotes modularity and independence within each component of the architecture while still allowing for communication with other systems.

## Debugging event channels

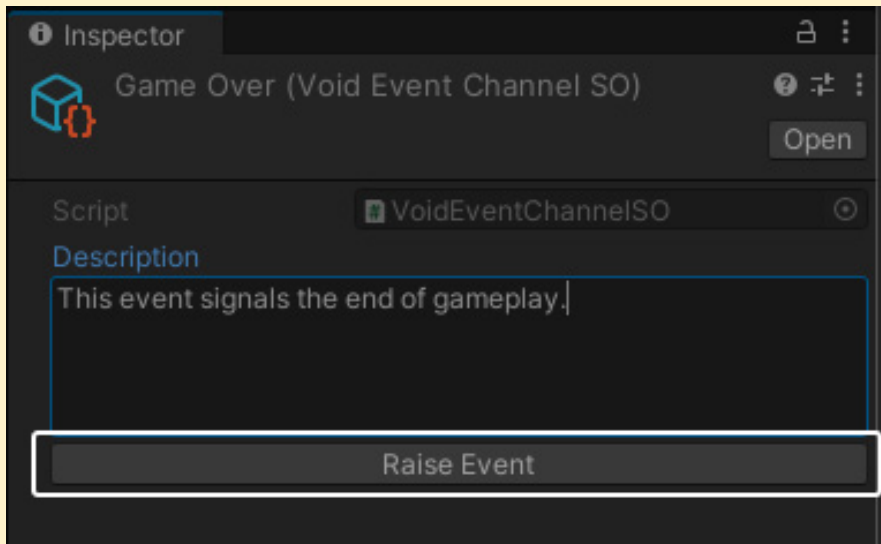
A custom Editor or property drawer can create a “Raise Event” button in the Inspector. This can help you manually invoke the event for debugging.

For example, here’s a basic Editor script that creates a custom Inspector button for the `VoidEventChannelSO`:

```
[CustomEditor(typeof(VoidEventChannelSO))]  
public class VoidEventChannelSOEditor : Editor  
{  
    public override void OnInspectorGUI()  
    {  
        DrawDefaultInspector();  
  
        VoidEventChannelSO eventChannel = (VoidEventChannelSO)target;  
  
        if (GUILayout.Button("Raise Event"))  
        {  
            eventChannel.RaiseEvent();  
        }  
    }  
}
```



This creates a button that allows you to raise the event at will, making it easier to diagnose issues at runtime.



A custom Editor button can help test event channels.

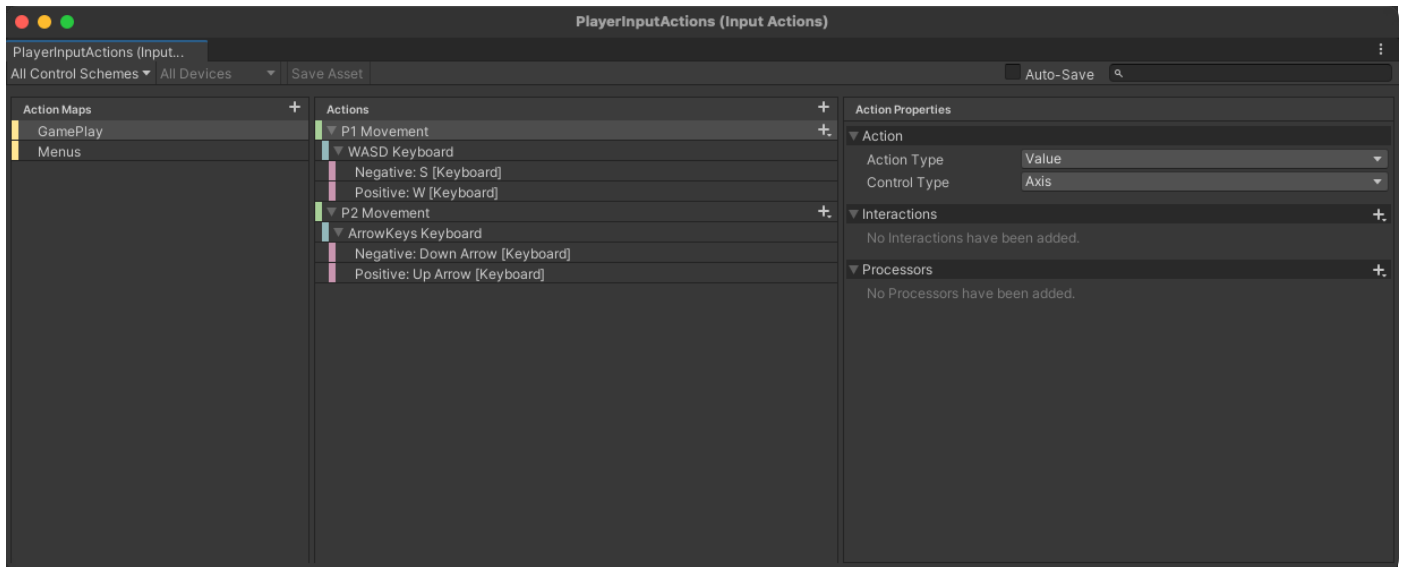
With a little more work, you can make buttons for event channels that carry data as well. Reserve a field for a debug value in the event channel itself, then pass this to the Editor script. You can find examples of how to implement this in the [SOAP](#) or [Unity Atoms](#) projects.

As you continue using event channels for object decoupling, consider developing debugging tools, such as keeping a record of all listeners for each event. The event channel class can have methods to subscribe and unsubscribe objects, making it easier to identify which events are causing specific behaviors during runtime.

## Example: InputReader

Objects that listen for user input need a specialized type of event channel. Unity's [Input System](#) uses [InputActions](#) to represent raw input data as logical concepts (e.g., jump, walk, etc.).

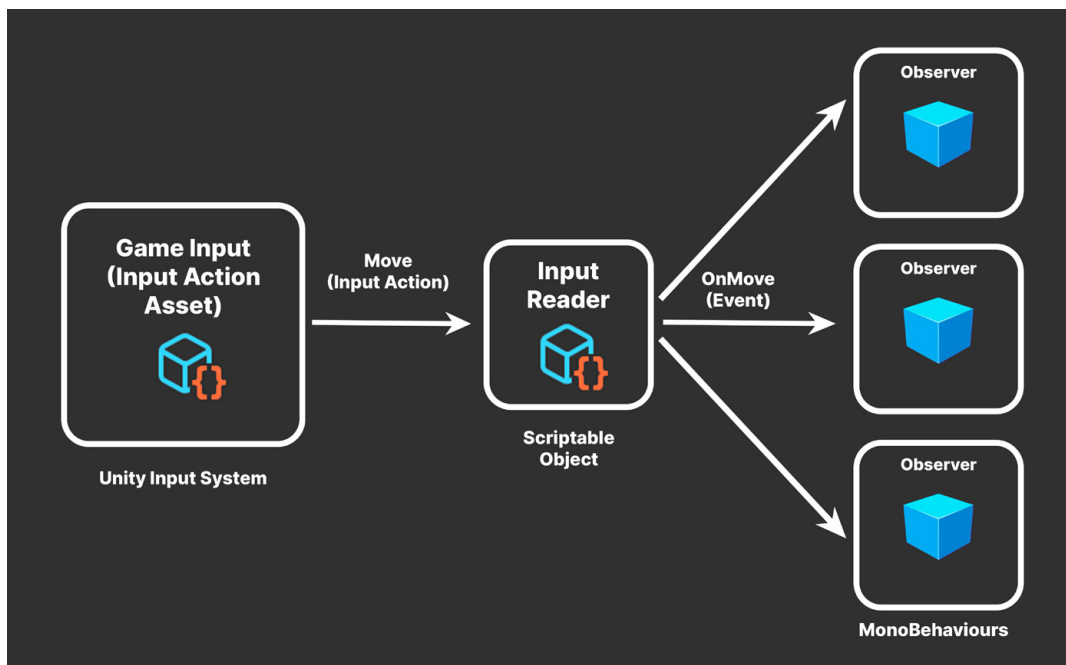
Each InputAction, in turn, includes its own started, performed, and canceled events.



Setting up Actions and Action Maps in the Input System Editor

In order to decipher the InputAction bindings, you can create a special InputReader ScriptableObject. Again, this acts as an intermediary between the subject and observers. In this case, however, MonoBehaviours won't raise the events explicitly.

Instead, the Input System takes the place of the subject or broadcaster:



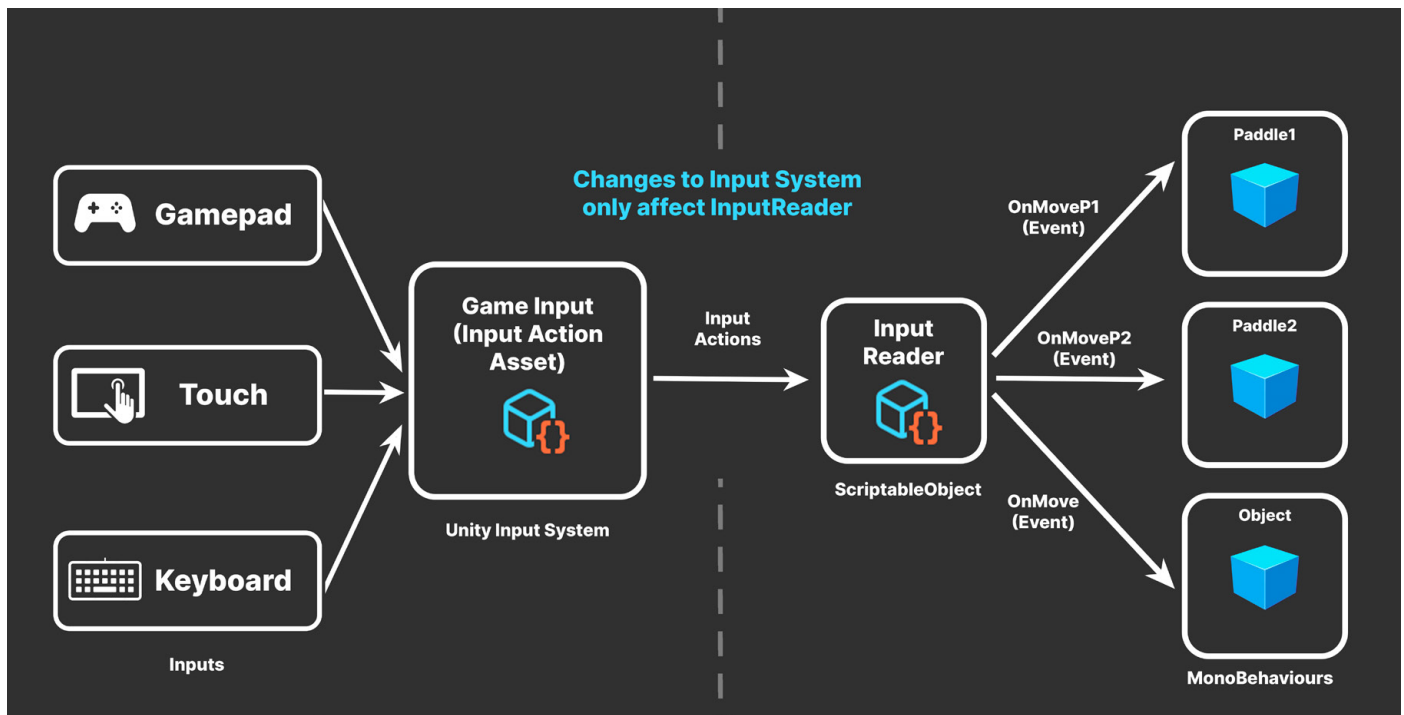
A ScriptableObject InputReader relays events from InputActions.

Here, we set up Actions and ActionMaps in the Input System. Each InputAction describes a separate axis of input and binds to the keyboard, gamepad, or whatever input device you like to use.





Rather than directly subscribing to the InputActions themselves, the paddle controllers listen for the `OnMoveP1` .performed event and `OnMoveP2` .performed events, respectively.



The InputReader insulates objects from direct dependency on the inputs.

The resulting InputReader standardizes how your GameObjects will process gamepad or keyboard actions. Any GameObject that needs input:

- Maintains a reference to the InputReader ScriptableObject
- Subscribes to the relevant events and connects its event-handling methods

While this pattern may be overkill for a smaller game, we demonstrate this to make the concept easier to digest.

The benefits won't be apparent until your project grows and you add many more components. Decoupling the inputs from the GameObjects consuming them gives added flexibility and reusability.

If you have to modify the InputActions during development, you only need to maintain the InputReader itself. The listening objects are unaffected if the events don't need to change. Thus, maintaining the connection from input to observers becomes less work – especially when you have a lot of observers.



## Static versus non-static events

You can choose to use static events to ease the burden of locating the `ScriptableObject` on the listening objects.

For example, a `MonoBehaviour` could subscribe to the `InputReader`'s static `MoveP1Event` and `MoveP2Event` events in its `OnEnable` method:

```
InputReader.MoveP1Event += OnMoveP1;
```

```
InputReader.MoveP2Event += OnMoveP2;
```

When using static events, be extra diligent when managing subscriptions. Don't forget to unsubscribe in `OnDisable`:

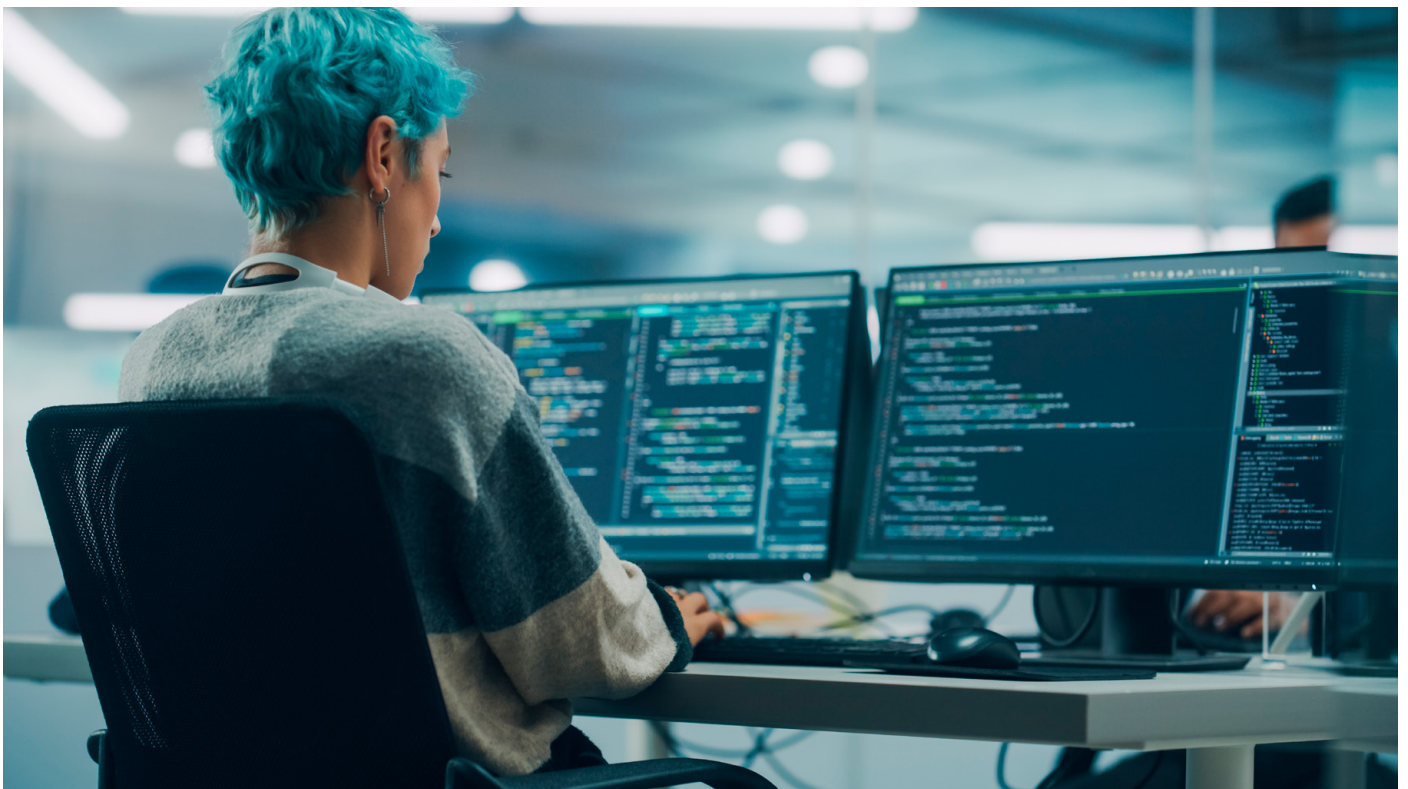
```
InputReader.MoveP1Event -= OnMoveP1;
```

```
InputReader.MoveP2Event -= OnMoveP2;
```

Static events will always be reachable and won't be collected by the garbage collector if they have active subscribers. Any dangling subscribers will prevent their cleanup for the duration of your application.

Static events, however, aren't serializable. If you want to work interactively in the Editor, choose non-static events and make sure you reference the appropriate `ScriptableObject` in the Inspector.

# The Command pattern



Instead of invoking a method directly, the command pattern allows you to encapsulate one or more method calls as a “command object.”



Then, you store these command objects in a collection, like a queue or a stack, which works as a small buffer. This gives you extra flexibility to control each command object's execution. Common applications include playing back a series of actions with specific timing or making those actions undoable.

You've likely encountered this in some of your favorite game genres:

- In a real-time strategy game, the command pattern could be used to queue up actions of units and buildings. The game would then execute each building command as resources became available or as a series of movement actions for the unit.
- In a turn-based strategy game, the player could select a unit and then store its moves or actions in a queue or other collection. At the end of the turn, the game could execute all of the commands in the player's queue.
- In a puzzle game, the command pattern could allow the player to undo and redo actions.
- In a fighting game, reading button presses or gamepad motions in a specific command list could perform combos and special moves.

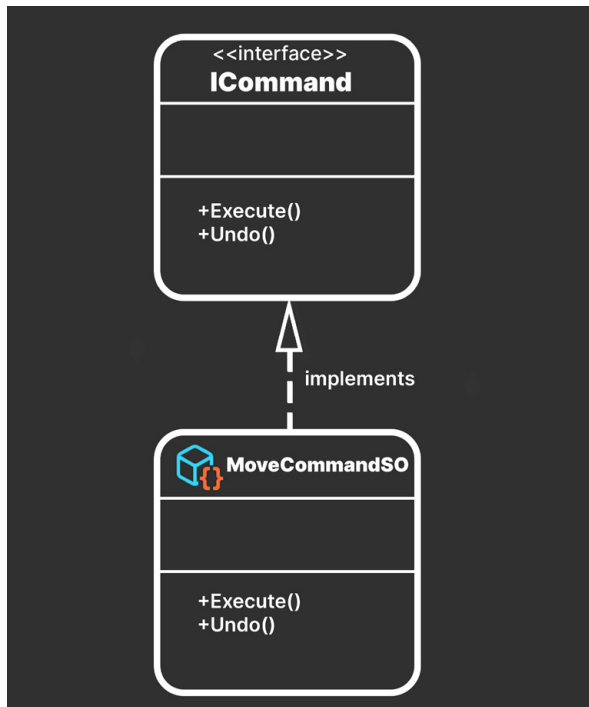
You can use ScriptableObjects to implement the command pattern.

For example, you could create a command to define a Transform's movement. Wrapping each action within a separate object results in extra control.

You'll define an interface ICommand an Execute method and an Undo method (you could also use an abstract class):

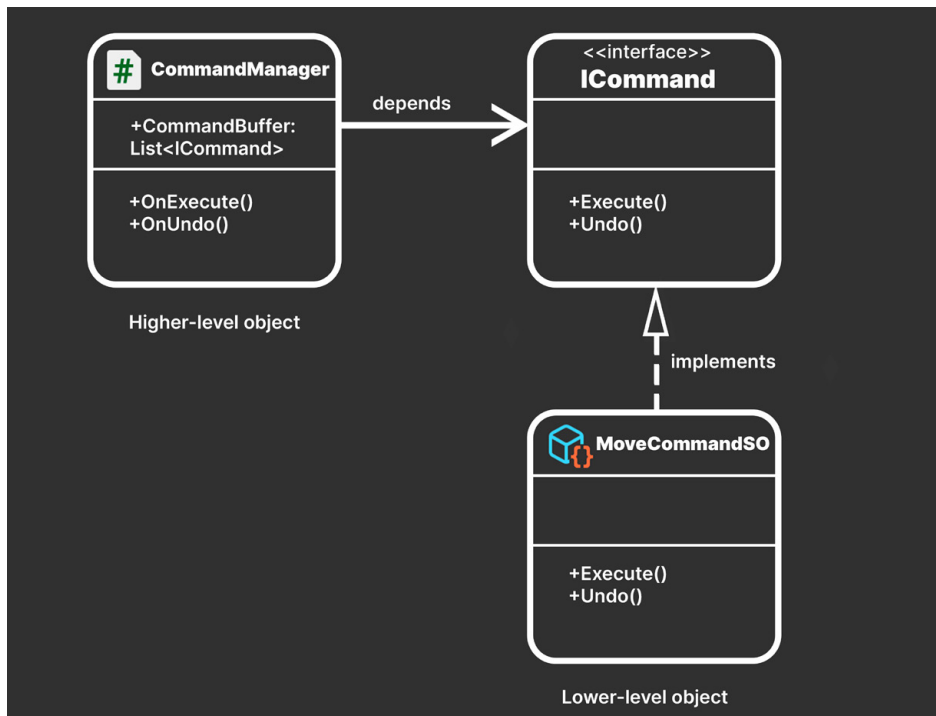
```
public interface ICommand
{
    public abstract void Execute();
    public abstract void Undo();
}
```

Then, have a ScriptableObject implement the ICommand interface. Each Command object fills out its own Execute and Undo methods with its own implementation details.



Implementing the command pattern with a ScriptableObject

A MonoBehaviour or ScriptableObject can then define a command buffer that will contain the command objects. This can be a collection, such as a list, stack, array, or queue.



A CommandManager maintains a collection of ICommand objects.



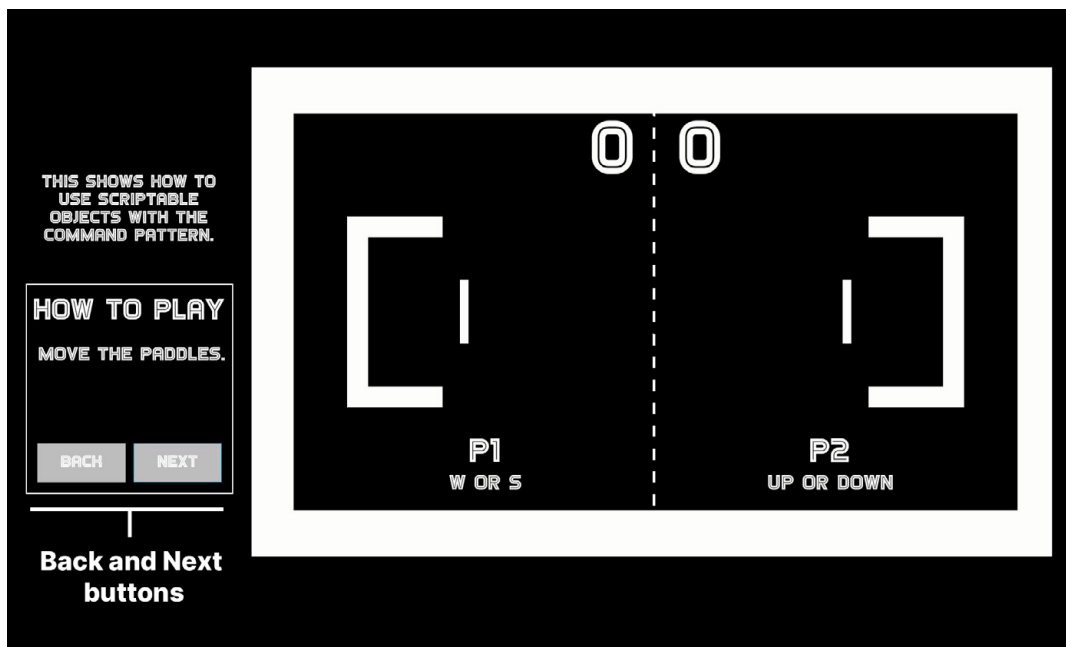
This simple structure lets you execute the commands in sequence. Imagine a tutorial or cutscene that moves a GameObject through a prescribed set of actions or animations. The command pattern is well suited for that.

Because each command is a separate object, it's easy to reorder them. Just decide how you want to maintain the CommandBuffer:

- If creating it as a stack, you push commands to the stack when executing them. When undoing an action, you can pop it off and keep a separate redo stack.
- If you're using a list or array, track the current Command's index, then increment or decrement the index as you need to undo or redo commands.

See the MoveCommandSO and CommandManager classes in the [sample project](#) for one example of undoable movement. Here, a rudimentary tutorial scene labels parts of the game board to explain how to play.

Click the Next button to advance through the explanatory text. Likewise, click the Back button to cycle in reverse through the instructions.



A simple implementation of the command pattern.

You can find out more about the command pattern in the e-book [Level up your code with design patterns and SOLID](#). Also, see this community post, [Command pattern with ScriptableObjects](#), which demonstrates this pattern with ScriptableObjects.



## ScriptableObjects or C# classes?

When deciding on the right code architecture for your project, it's important to consider the skills and preferences of your team, as well as your game's performance requirements. While some designers may prefer to use the Unity Editor interactively, others may prefer to work entirely in C# code.

Take these factors into account when creating a codebase that's easy for everyone on your team to work with. Of course, no design pattern is a one-size-fits-all solution, and it's important to carefully evaluate the pros and cons of each before implementing it.

Remember that the "right" code architecture is just the one that works best for your team and your project.

# The Runtime Set pattern

At runtime, you'll often need to track a list of `GameObjects` or components in your scene. For example, you may need to maintain a list of enemies or NPCs.

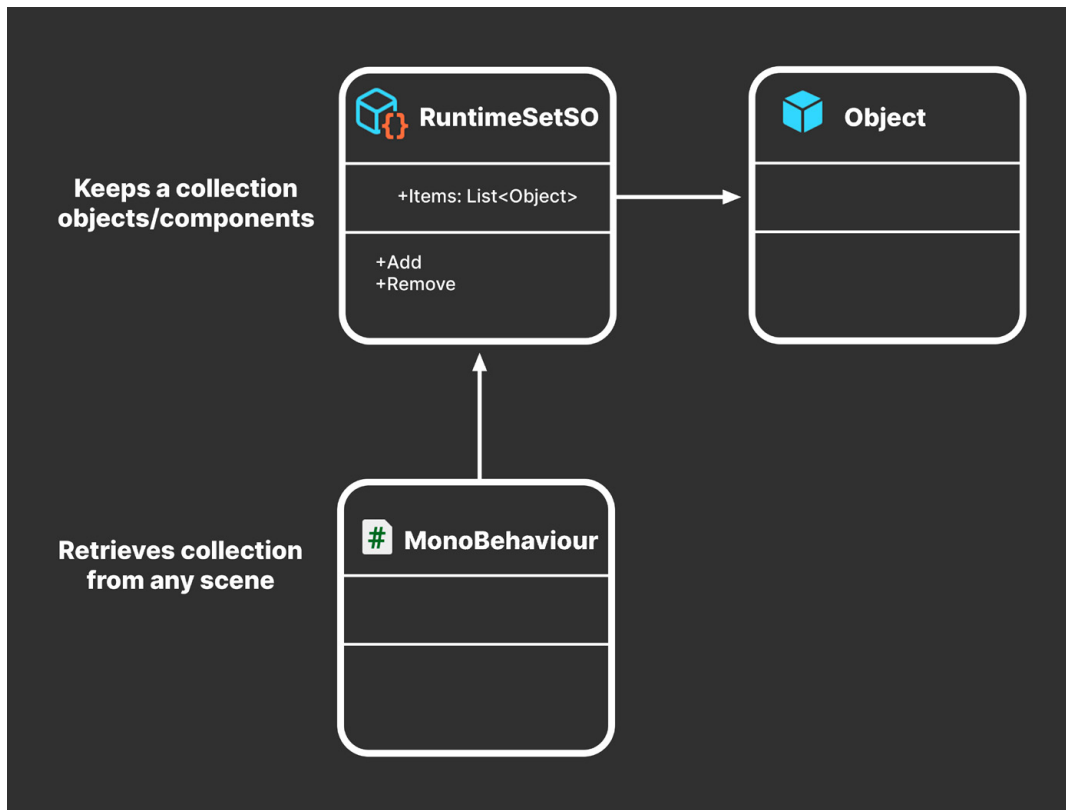
Because a `ScriptableObject` instance appears at the project level, it can store data that's available to any object from any scene. Again, this replicates much of the easy global access of a singleton without that pattern's known drawbacks.

Reading data directly from a `ScriptableObject` is also more optimal than searching the Scene Hierarchy with a find operation such as `Object.FindObjectOfType` or `GameObject.FindWithTag`. Depending on your use case and the size of your hierarchy, these are relatively expensive methods that can be inefficient for per-frame updates.

## Basic Runtime Set

Instead, consider storing data on a `ScriptableObject` as a "Runtime Set." This is a specialized data container that maintains a public collection of elements but also provides basic methods to add and remove to the collection.





A Runtime Set provides global access to a collection of data.

Here's a basic Runtime Set that tracks a list of GameObjects:

```
using System.Collections.Generic;
using UnityEngine;

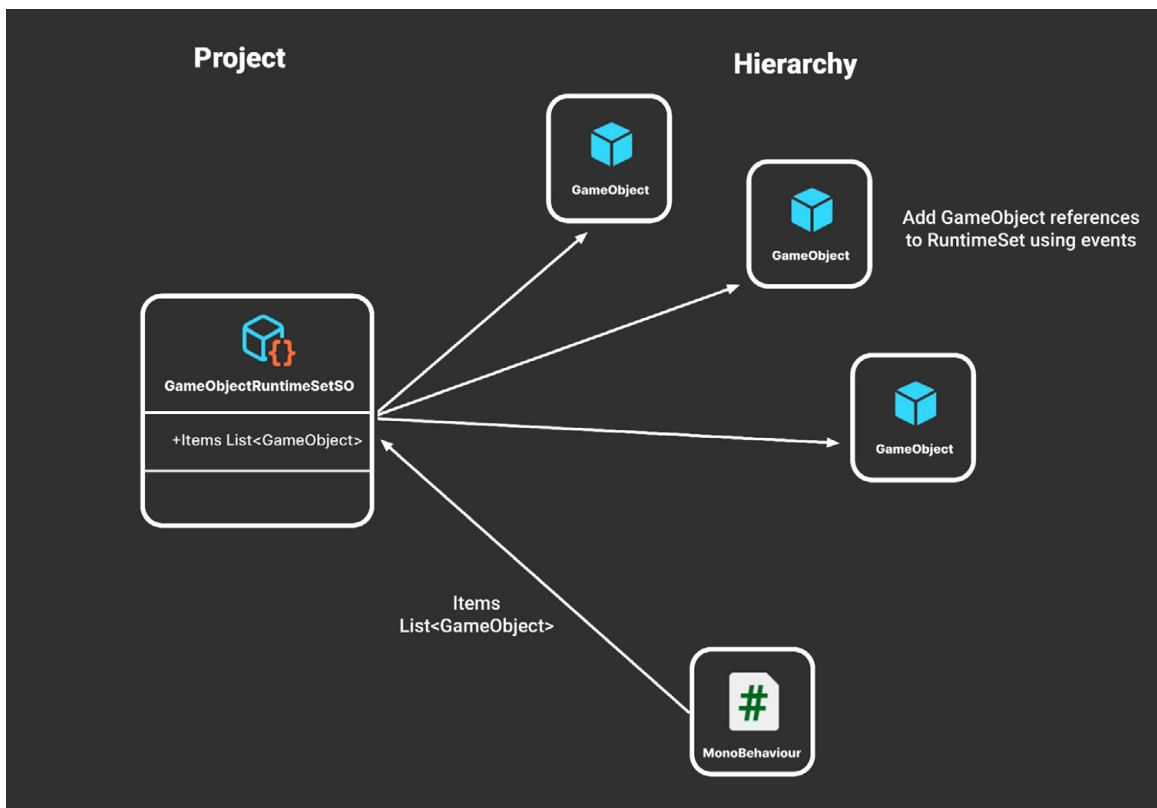
[CreateAssetMenu(menuName = "GameObject Runtime Set", fileName = "GORuntimeSet")]
public class GameObjectRuntimeSetSO : ScriptableObject
{
    private List<GameObject> items = new List<GameObject>();
    public List<GameObject> Items => items;

    public void Add(GameObject thingToAdd)
    {
        if (!items.Contains(thingToAdd))
            items.Add(thingToAdd);
    }
}
```



```
public void Remove(GameObject thingToRemove)
{
    if (items.Contains(thingToRemove))
        items.Remove(thingToRemove);
}
```

At runtime, any MonoBehaviour can reference the public Items property to obtain the full list. Another script or component must be responsible for managing how the GameObjects are added or removed from this list.



A GameObject Runtime Set

Reference the Runtime Set in a MonoBehaviour. Then, in the `OnEnable` and `OnDisable` event functions, add or remove the object from the Runtime Set's Items list. Alternatively, use an event channel to send a GameObject as its payload (e.g., `GameObjectEventChannel`).



## Generic version

You may want to use a Runtime Set with a specific type of MonoBehaviour. For instance, this could allow you to maintain a list of enemy or pickup items accessible to anything in your scene. In that case, you could create specific Runtime Sets for each type (e.g., EnemyRuntimeSet, PickupRuntimeSet, etc.).

One way to streamline the creation of additional Runtime Sets is to use a generic abstract class:

```
public abstract class RuntimeSetSO<T> : ScriptableObject
{
    [HideInInspector]
    public List<T> Items = new List<T>();

    public void Add(T thing)
    {
        if (!Items.Contains(thing))
            Items.Add(thing);
    }

    public void Remove(T thing)
    {
        if (Items.Contains(thing))
            Items.Remove(thing);
    }
}
```

This works similarly to the original GameObjectRuntimeSet but with added flexibility. If you wanted to create a Runtime Set for a custom Foo component, you would create a concrete FooRuntimeSetSO like so:

```
[CreateAssetMenu(menuName = "Foo Runtime Set", fileName = "FooRuntime-Set")]
public class FooRuntimeSetSO : RuntimeSet<Foo>
{
}
```



Build as many concrete classes as needed for gameplay (e.g., enemies, NPCs, inventory items, quests, and more can all have their own Runtime Sets). You just need to declare a new empty class with the right type.

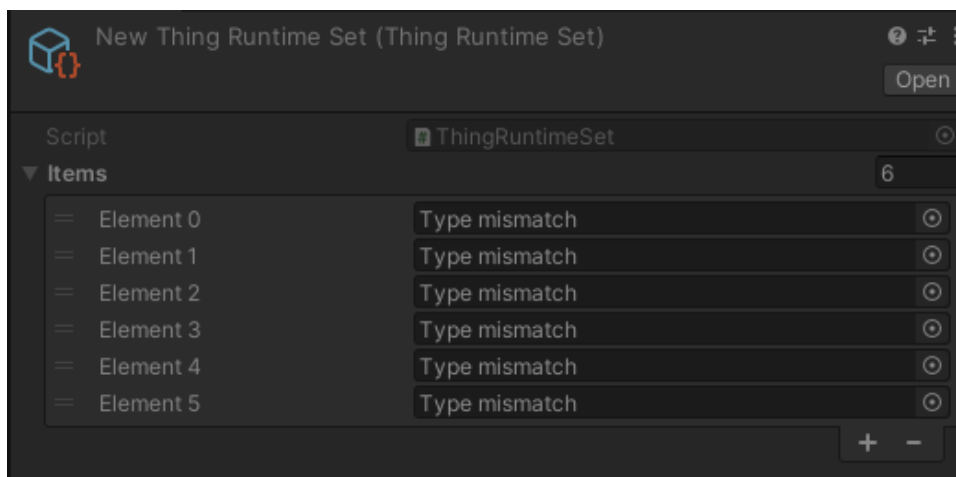
As an alternative to using events, each Foo component can add or remove itself using its `OnEnable` or `OnDisable` methods. Then, if you set the `FooRuntimeSet` field in the Inspector, the Foo component will appear in the Runtime Set automatically. This is especially handy if you're using the Foo component with prefabs.

```
public class Foo : MonoBehaviour
{
    public FooRuntimeSetSO RuntimeSet;

    private void OnEnable()
    {
        RuntimeSet.Add(this);
    }

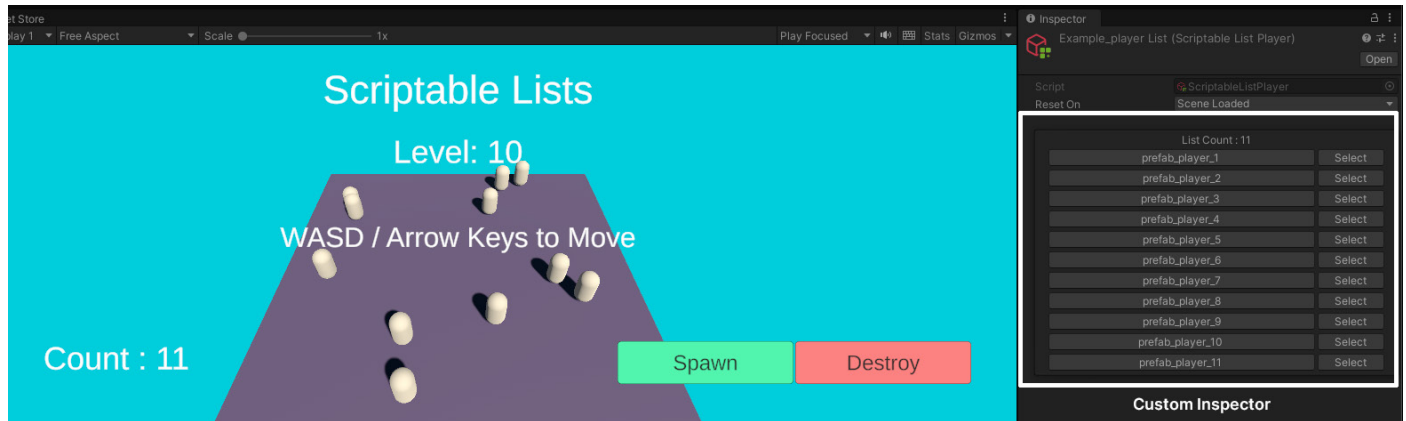
    private void OnDisable()
    {
        RuntimeSet.Remove(this);
    }
}
```

Note: One limitation of this technique is that if you inspect the `ScriptableObject` at runtime, you won't be able to see the contents of the Runtime Set list in the Inspector. If you try to publicly expose the list in the Inspector, you'll see this:



Runtime Sets won't show scene objects or components in the Inspector.

By default, a “Type mismatch” appears in each element field since a ScriptableObject won’t be able to serialize a scene object. The list works normally, but the data does not display correctly. Use a public property or the [HideInInspector](#) attribute if you want to avoid confusion and prevent the list from showing in the Inspector. You can also fix this issue with a custom Editor script and Inspector. For a good example of this, see [SOAP \(ScriptableObject Architectural Pattern\)](#) on the Asset Store.



A custom Editor in SOAP shows the contents of a Runtime Set.

## Fun facts about foo and bar

The terms [foo](#) and [bar](#) are common placeholder names in programming. These terms were likely chosen because they are short, easy to remember, and sound distinctive.

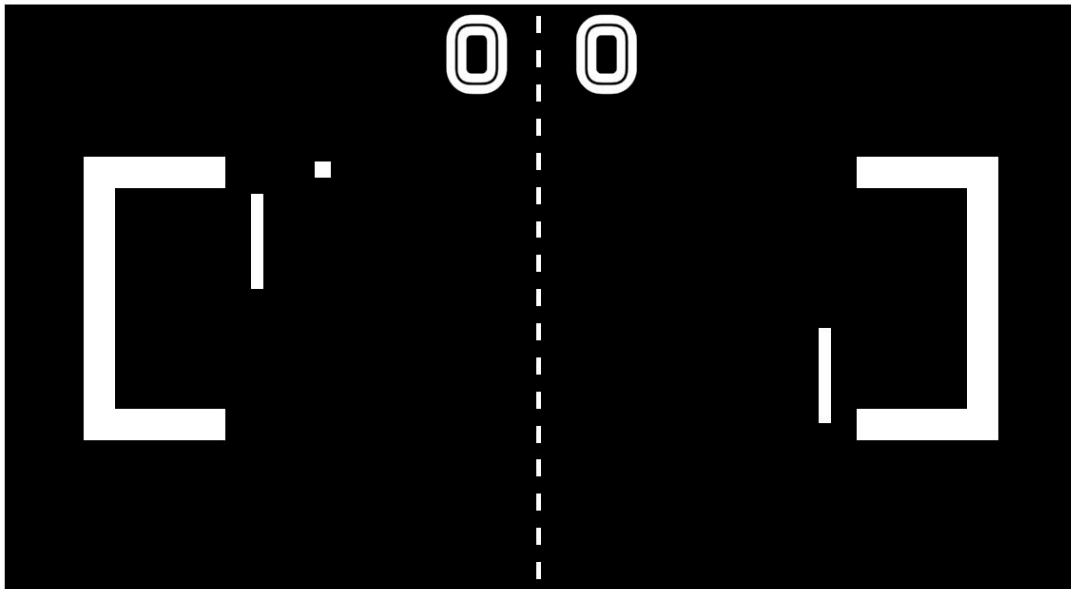
While their exact origins are unclear, some people believe that the terms originated from radar operators in World War II. The nonsense word “foo” also appeared as a catchphrase in a [1930's comic strip](#).

In a programming context, their use is generally credited to the [Tech Model Railroad Club](#) at MIT circa the 1960s. The MIT train room had two general-purpose buttons by the door labeled “foo” and “bar.” MIT hackers often repurposed these names for their ideas, hence the adoption of foo and bar as general variable names. Today, the use of foo and bar as dummy variable names is a widespread convention in the programming community.

# Explore the sample project

Accompanying this guide is [a sample project](#) for you to work with and learn about ScriptableObjects. Inspired by classic ball and paddle game mechanics, this project is a great opportunity to see how ScriptableObjects can improve the architecture of your Unity project.

By following SOLID principles and using techniques often employed in larger projects, you can demonstrate how ScriptableObjects can help to restructure your code.



The sample project



Here, you will have the chance to see how ScriptableObjects can be applied, and gain a better understanding of how they can be used to improve the efficiency and organization of your projects.

The sample includes many of the patterns explored in this guide:

- **Data containers:** Shared settings data is extracted as ScriptableObjects. Then, gameplay settings or common states are stored as assets in the project. Also, you can change the initial level layout by swapping ScriptableObjects.
- **Extendable enums:** Empty ScriptableObjects function as enums to categorize different players.
- **Delegate objects:** A simple audio delegate shows how you can randomize the ball's collision sounds just by swapping ScriptableObjects. Objectives are also ScriptableObjects that plug into the game management system for determining win-lose conditions.
- **Event channels:** The observer pattern helps you set up game events for UI, sounds, and scoring. Different GameObjects can subscribe to different "event channels," similar to tuning in to a specific radio broadcast.
- **Dual serialization:** Some game data is stored like the level layout in ScriptableObjects for ease of use in the Editor but with the option to save it as JSON files. Externally modded JSON data can then rebuild a ScriptableObject, which works with the original setup script.

Of course, the game itself is not the main focus of this sample. A paddle-and-ball arcade game can be built with far fewer lines of code. Instead, the idea with [the sample project](#) is to demonstrate how ScriptableObjects can help you create components that are testable and scalable, while still being designer-friendly.

# Conclusion

ScriptableObjects can be a versatile addition to your toolset. Think of these design patterns as extra possibilities for organizing your Unity development.

Note that you can achieve many of the techniques in this guide using C# classes instead of ScriptableObjects, and there will always be developers who prefer to do this in some scenarios. However, the Unity Editor provides the convenience of viewing and editing ScriptableObjects more easily. This can help your artistic and design teams interface with your project, instead of having everything being controlled through code.

Do your designers want to set up gameplay data without constant support from the software team? If so, then maybe Scriptable Objects have a place in your project.

Of course, not using a pattern can be just as valuable as using one. What may seem like a natural fit for one application may not be for another. Evaluate the advantages and disadvantages of a pattern before deploying it.

There are no hard-and-fast rules for how to structure your Unity project. Balance the skill sets and personal preferences of your team with your code architecture.

Then, you can focus on the important thing: making your game an engaging experience for your players.



# More resources

## Documentation

- The ScriptableObject [Scripting API](#)
- ScriptableObjects [Manual page](#)

## Technical e-books from Unity

### Related to design patterns and coding in Unity

- [Level up your code with design patterns and SOLID](#) contains an introduction to SOLID development and design patterns in Unity.
- [Create a C# style guide \(Unity 6 edition\)](#) covers some of the best practices when setting up your project.

### Other best practice guides

- [Advanced best practice guides](#) in Unity documentation
- [Unity best practices hub](#)



## From Unite

- [Overthrowing the MonoBehaviour tyranny in a glorious ScriptableObject revolution](#)
- [Game Architecture with ScriptableObjects](#)

For general information about code architecture, we also recommend:

- [From \*Pong\* to 15-person project](#)

## More project examples

These community project examples show extensive use of ScriptableObjects in their architecture:

- The [Tanks Demo](#) presentation from Unite, by Richard Fine, uses ScriptableObjects to customize audio, pluggable AI, and destructible buildings.
- Ryan Hipple, a senior full stack game engineer at Meta, has a [GitHub project](#) that illustrates much of his Unite Austin presentation. You can also read his corresponding [blog post](#).
- [Soap \(Scriptable Object Architectural Pattern\)](#) on the Asset Store implements many of the patterns described in this e-book and adds many quality of life features when working with Scriptable Objects.
- The [Unity Atoms](#) project is an open source library that makes extensive use of ScriptableObjects. Read [this page](#) to get started with it.
- The [Reactive Menu System](#) uses ScriptableObjects to build a UGUI system to handle UI state changes and menu management.
- The [Unity Open Project \(Chop Chop\)](#) heavily relies on ScriptableObjects and manages gameplay with event channels.

## For game designers

Christo Nobbs, a senior technical game designer who specializes in systems game design and Unity (C#), was a contributor to [The Unity game designer playbook](#), as well as the main author of a short series of blog posts on designing game systems in Unity:

- [Systems that create ecosystems: Emergent game design](#)
- [Unpredictably fun: The value of randomization in game design](#)
- [Animation curves, the ultimate design lever](#)



## Professional training

Unity Professional Training offers both online and in-person training to give you and your team additional skills and knowledge to work more productively, and collaborate efficiently, in Unity. Learn more about Unity Professional Training [here](#).



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