Value vs. Reference

Learn how some data types are copied by value and others by reference, and what this means when we write code. This concept is at the root of countless bugs that plague websites today. A simple look at computer memory explains what's happening.

Preface

I'd like to begin this lesson by saying that this lesson is meant to provide a useful model for understanding the behavior of variables in JavaScript. It is not necessarily how engines implement the behavior of variables, as each engine may do it differently, but it provides a model that fits the behavior correctly and helps explain what we observe.

As you advance in your software career, you'll gain a deeper understanding of how values are treated. For now, this lesson will provide a suitable model for understanding the behavior we observe when working with variables in JavaScript.

Values & References

JavaScript has 5 data types that are copied by ***value***: `Boolean`, `null`, `undefined`, `String`, and `Number`. We'll call these **primitive types**.

JavaScript has 3 data types that are copied by having their ***reference*** copied: `Array`, `Function`, and `Object`. These are all technically Objects, so we'll refer to them collectively as **Objects**.

Primitives

If a primitive type is assigned to a variable, we can think of that variable as *containing* the primitive value.

```
const x = 10;
const y = 'abc';
const z = null;
```

`x` *contains* `10`. `y` *contains* `'abc'`. To cement this idea, we'll maintain an image of what these variables and their respective values look like in memory.

Variables	Values
`x`	`10`
`y`	`'abc'`
`z`	`null`

When we assign these variables to other variables using `=`, we **copy** the value to the new variable. They are copied by value.

```
const x = 10;
const y = 'abc';

const a = x;
const b = y;

console.log(x, y, a, b);
// -> 10, 'abc', 10, 'abc'
```

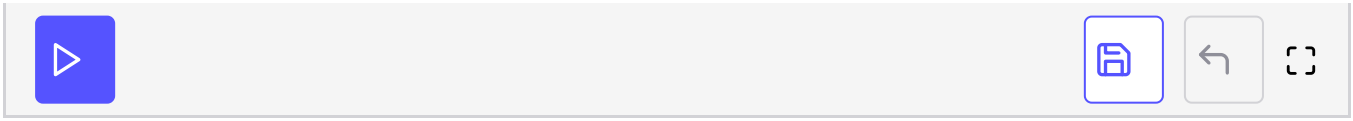
Both `a` and `x` now contain `10`. Both b and y now contain `'abc'`. They're separate, as the values themselves were copied.

Variables	Values
`x`	`10`
`y`	`'abc'`
`a`	`10`

`b`	`'abc'`

Changing one does not change the other. Think of the variables as having no relationship to each other.

```
const x = 10;
const y = 'abc';

let a = x;
let b = y;

a = 5;
b = 'def';

console.log(x, y, a, b); // -> 10, 'abc', 5, 'def'
```



Objects

This will feel confusing, but bear with me and read through it. Once you get through it, it'll seem easy.

Variables that are assigned a non-primitive value are given a *reference* to that value. That reference points to the object's location in memory. The variables don't actually contain the value.

Objects are created at some location in our computer's memory. When we write `arr = []`, we've created an array in memory. What the variable `arr` now contains is the address, the location, of that array.

Let's pretend that **address** is a new data type that is passed by value, just like number or string. An address points to the location, in memory, of a value that is passed by reference. Just like a string is denoted by quotation marks (`''` or `""`), an address will be denoted by arrow brackets, <>.

When we assign and use a reference-type variable, what we write and see is:

```
1) const arr = [];
2) arr.push(1);
```

A representation of lines 1 and 2 above in memory is:

1.

Variables	Values		Addresses	Objects
`arr`	<#001>		#001	`[]`

2.

Variables	Values		Addresses	Objects
`arr`	<#001>		#001	`[1]`

Notice that the value, the address, contained in the variable `arr` is **static**. The array in memory is what changes. When we use `arr` to do something, such as pushing a value, the JavaScript engine goes to the location of arr in memory and works with the information stored there.

Assigning by Reference

When a reference type value, an object, is copied to another variable using `=`, the address of that value is what's actually copied over *as if it were a primitive*. **Objects are copied by copying the reference** instead of by copying the value. The object itself is unchanged and static. The only thing copied is the reference, the address, of the object.

```
const reference = [1];
const refCopy = reference;
```

The code above looks like this in memory.

Variables	Values		Addresses	Objects
`reference`	<#001>		#001	`[1]`
`refCopy`	<#001>			

Each variable now contains a reference to the *same array*. They have the same address. That means that if we alter `reference`, `refCopy` will see those changes:

```
reference.push(2);
console.log(reference, refCopy);
// -> [1, 2], [1, 2]
```

Variables	Values		Addresses	Objects
`reference`	<#001>		#001	`[1, 2]`
`refCopy`	<#001>			

We've pushed `2` into the array in memory. When we use `reference` and `refCopy`, we're pointing to that same array.

Reassigning a Reference

Reassigning a reference variable replaces the old reference.

```
const obj = { first: 'reference' };
```

In memory:

Variables	Values		Addresses	Objects
`obj`	<#234>		#234	`{ first: 'reference' }`

When we have a reassignment:

```
let obj = { first: 'reference' };
```

```
obj = { second: 'ref2' }
```

The address stored in `obj` changes. The first object is still present in memory, and so is the next object:

Variables	Values	Addresses	Objects
`obj`	<#678>	#234	`{ first: 'reference' }`
		#678	`{ second: 'ref2' }`

When there are no references to an object remaining, as we see for the address **#234** above, the JavaScript engine can perform garbage collection. This just means that the programmer has lost all references to the object and can't use the object anymore, so the engine can safely delete it from memory.

In this case, the object `{ first: 'reference' }` is no longer accessible through any variables and is available to the engine for garbage collection.

== and ===

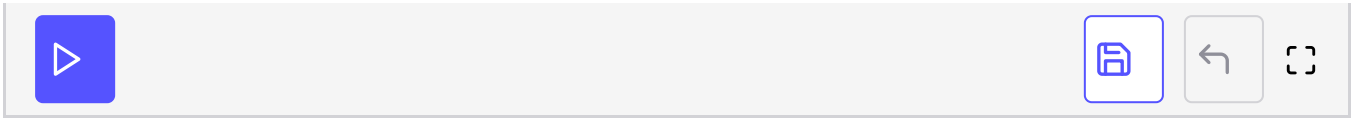
When the equality operators, `==` and `===`, are used on reference-type variables, they check the reference. If the variables contain a reference to the same item, the comparison will result in `true`.

```
const arrRef = ['Hi!'];
const arrRef2 = arrRef;

console.log(arrRef === arrRef2); // -> true
```

If they're distinct objects, even if they contain identical items, the comparison will result in `false`.

```
const arr1 = ['Hi!'];
```

```
const arr2 = ['Hi!'];

console.log(arr1 === arr2); // -> false
```



Comparing Objects

If we have two distinct objects and want to see if their properties are the same, the comparison operators will be of no use. We have to write a function that checks each property in both objects and makes sure they are the same. For two arrays, we'll need a function that traverses the arrays and checks each item as it goes.

Passing Parameters through Functions

When we pass primitive values into a function, the function copies the values into its parameters. It's effectively the same as using `=`.

```
const hundred = 100;
const two = 2;

function multiply(x, y) {
    // PAUSE
    return x * y;
}

const twoHundred = multiply(hundred, two);
```

In the example above, we give `hundred` the value `100`. When we pass it into `multiply`, the variable `x` gets that value, `100`. The value is copied over as if we used an `=` assignment. Again, the value of `hundred` is not affected.

Here is a snapshot of what the memory looks like right at the `// PAUSE` comment line in `multiply`.

Variables	Values		Addresses	Objects
`hundred`	`100`		#333	`function(x, y) { ... }`

`two`	`2`			
`multiply`	<#333>			
`x`	`100`			
`y`	`2`			

`multiply` contains a reference to its function and the other variables contain primitives.

Pure Functions

We refer to functions that don't affect anything in the outside scope as *pure functions*. As long as a function only takes primitive values as parameters and doesn't use any variables in its surrounding scope, it is automatically pure, as it can't affect anything in the outside scope. All variables created inside are garbage-collected as soon as the function returns.

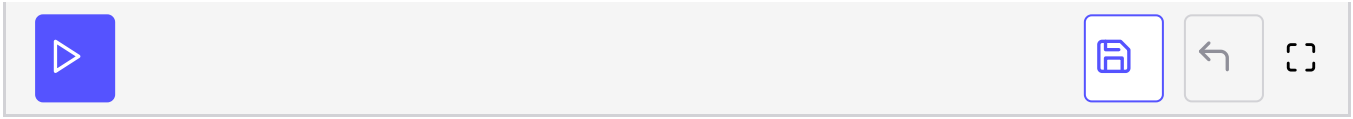
A function that takes in an Object, however, can mutate the state of its surrounding scope. If a function takes in an array reference and alters the array that it points to, perhaps by pushing to it, variables in the surrounding scope that reference that array see that change. After the function returns, the changes it makes persist in the outer scope. This can cause undesired side effects that can be difficult to track down.

Many native array functions, including Array.map and Array.filter, are therefore written as pure functions. They take in an array reference and internally, they copy the array and work with the copy instead of the original. This makes it so the original is untouched, the outer scope is unaffected, and we're returned a reference to a brand new array.

Let's go into an example of a pure vs. impure function.

```
function changeAgeImpure(person) {
    person.age = 25;
    return person;
}

const alex = {
```

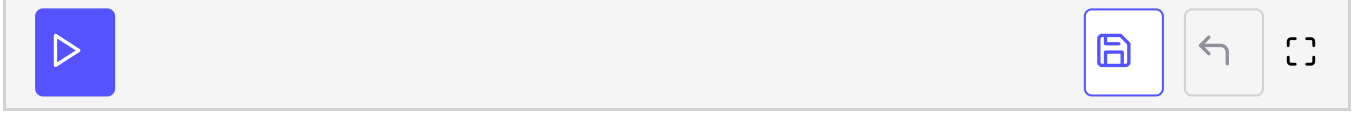
```
    name: 'Alex',
    age: 30
};

const changedAlex = changeAgeImpure(alex);

console.log(alex); // -> { name: 'Alex', age: 25 }
console.log(changedAlex); // -> { name: 'Alex', age: 25 }
console.log(alex === changedAlex); // -> true
```



This impure function takes in an object and changes the property age on that object to be `25`. Because it acts on the reference it was given, it directly changes the object `alex`. Note that when it returns the `person` object, it is returning the exact same object that was passed in. `alex` and `alexChanged` contain the same reference. It's redundant to return the `person` variable and to store that reference in a new variable.

Let's look at a pure function.

```
function changeAgePure(person) {
    const newPersonObj = JSON.parse(JSON.stringify(person));
    newPersonObj.age = 25;
    return newPersonObj;
}

const alex = {
    name: 'Alex',
    age: 30
};

const alexChanged = changeAgePure(alex);

console.log(alex); // -> { name: 'Alex', age: 30 }
console.log(alexChanged); // -> { name: 'Alex', age: 25 }
console.log(alex === alexChanged); // -> false
```



In this function, we use `JSON.stringify` to transform the object we're passed into a string, and then parse it back into an object with `JSON.parse`. This isn't the best way to duplicate an object, but it'll work here.

By performing this transformation and storing the result in a new variable, we've created a new object. The new object has the same properties as the original but it is a distinctly separate object in memory.

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When we change the `age` property on this new object, the original is unaffected. This function is now pure. It can't affect any object outside its own scope, not even the object that was passed in.

The new object needs to be returned and stored in a new variable or else it gets garbage collected once the function completes, as the object is no longer in scope.

Test Yourself

Value vs. reference is a concept often tested in coding interviews. Try to figure out for yourself what's logged here.

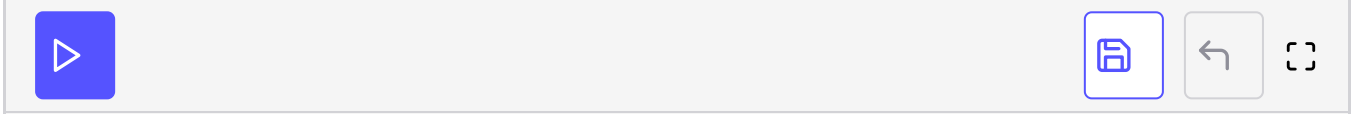
```
function changeAgeAndReference(person) {
    person.age = 25;
    person = {
      name: 'John',
      age: 50
    };

    return person;
}

const personObj1 = {
    name: 'Alex',
    age: 30
};

const personObj2 = changeAgeAndReference(personObj1);

console.log(personObj1); // -> ?
console.log(personObj2); // -> ?
```



The function first changes the property age on the original object it was passed in. It then reassigns the variable to a brand new object and returns that object. Here's what the two objects are logged out.

```
console.log(personObj1); // -> { name: 'Alex', age: 25 }
console.log(personObj2); // -> { name: 'John', age: 50 }
```

Remember that assignment through function parameters is essentially the same as an assignment with `=`. The variable `person` in the function contains a

same as an assignment with `=`. The variable `person` in the function contains a

reference to the `personObj1` object, so it initially acts directly on that object. Once we reassign person to a new object, it stops affecting the original.

This reassignment does not change the object that `personObj1` points to in the outer scope. `person` has a new reference because it was reassigned but this reassignment doesn't change `personObj1`.

An equivalent piece of code to the above block would be:

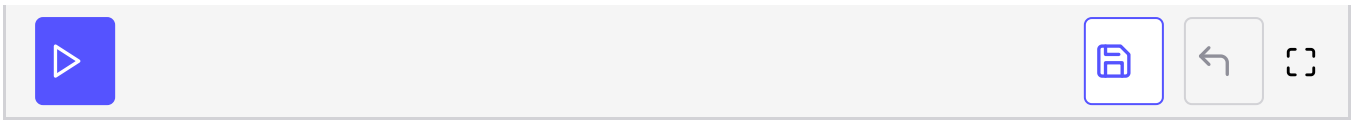
```
const personObj1 = {
    name: 'Christa',
    age: 20
};

let person = personObj1;
person.age = 25;

person = {
    name: 'John',
    age: 50
};

const personObj2 = person;

console.log(personObj1); // -> { name: 'Christa', age: 25 }
console.log(personObj2); // -> { name: 'John', age: 50 }
```



The only difference is that when we use the function, `person` is no longer in scope once the function ends.

That's it.

Quiz

Feel free to test your understanding.

Value vs. Reference

1 What will this print out?

What will this print out?

```
const obj = {
    innerObj: {
        x: 9
    }
};

const z = obj.innerObj;

z.x = 25;

console.log(obj.innerObj.x);
```

2

What will this print out?

```
const obj = {
    arr: [{ x: 17 }]
};

let z = obj.arr;

z = [{ x: 25 }];

console.log(obj.arr[0].x);
```

3

What will this print out?

```
const obj = {
    arr: []
};

obj.arr.push(17);

console.log(obj.arr === [17]);
```

Check Answers