Little Tricky Logic:
Misconceptions in the Understanding of LTL

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NJPLS

RQ. In **what ways** is LTL tricky, and **what can we do** about it?

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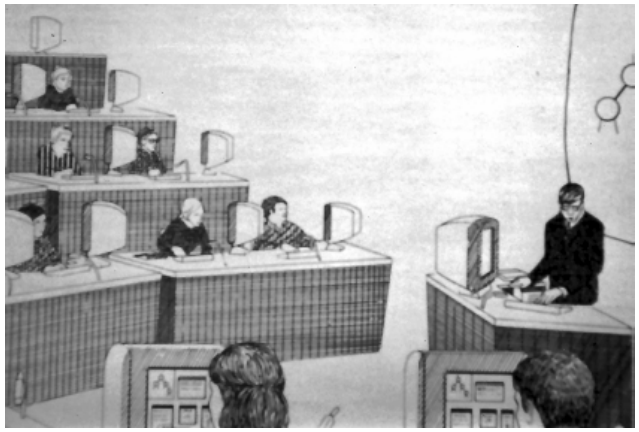
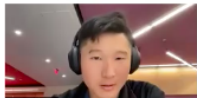
+2 years of studies with researchers and students





qualtrics

Quiz Time!

Quiz Format:

one question,
many answers,
you decide yes/no for each

✓ ✗

Question

✓ Possible Answer 1

✗ Possible Answer 2

✓ .....

LTL Operators:

```
always
eventually
after
until
```

Part 1:

Formulas vs. Traces

Q. Do the traces below satisfy the formula?

`{eventually Red} and {eventually Green}`

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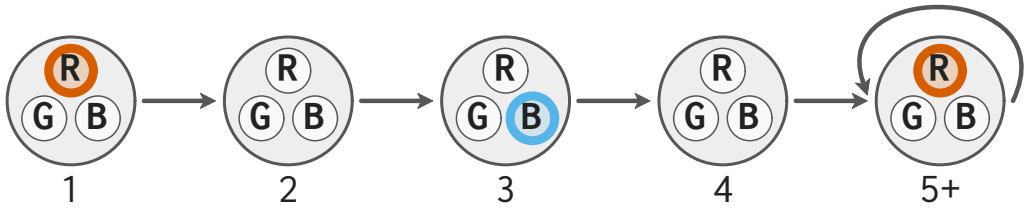

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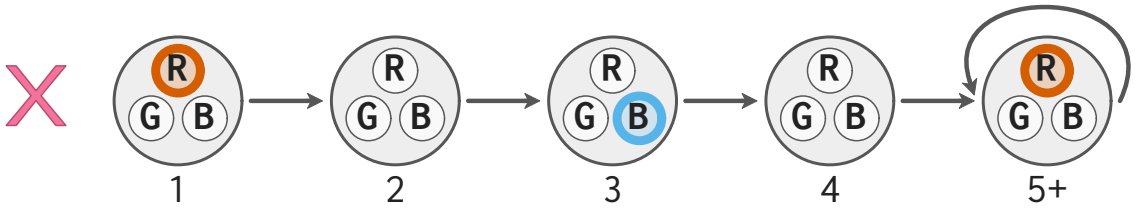

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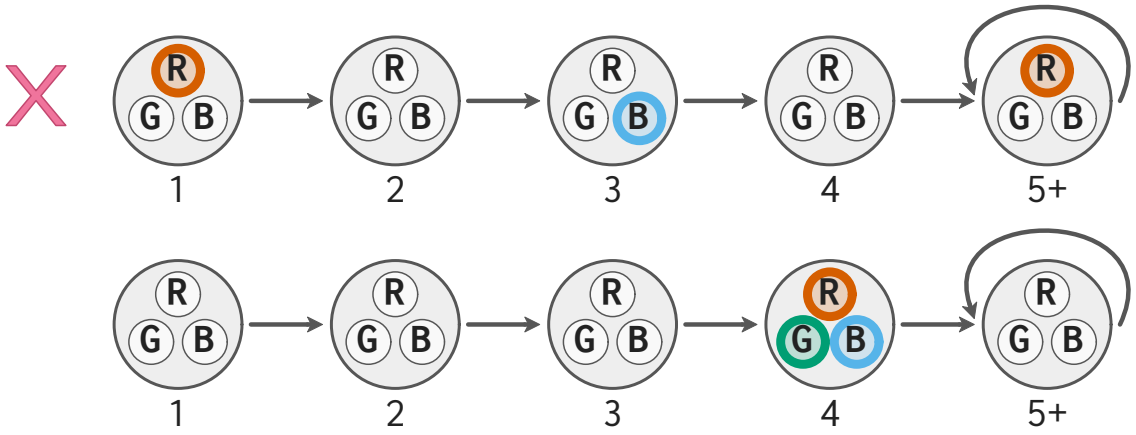

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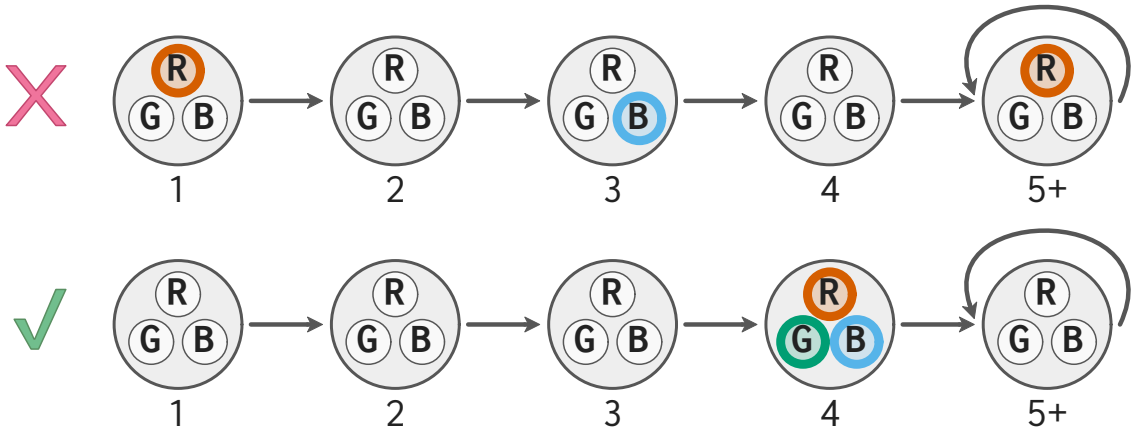

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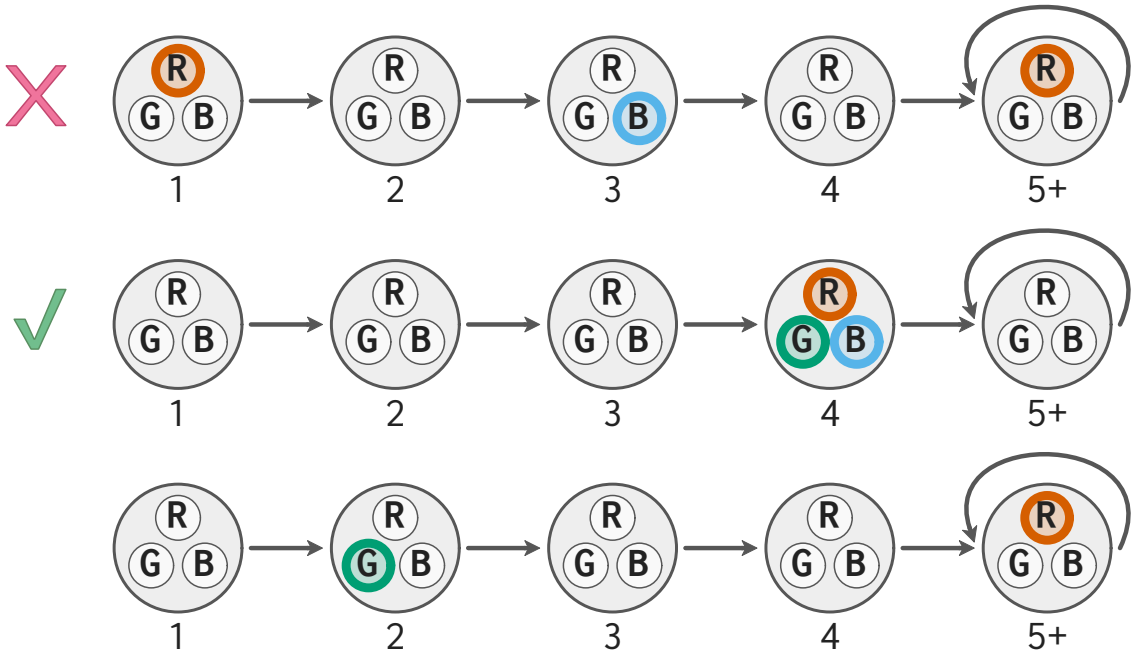

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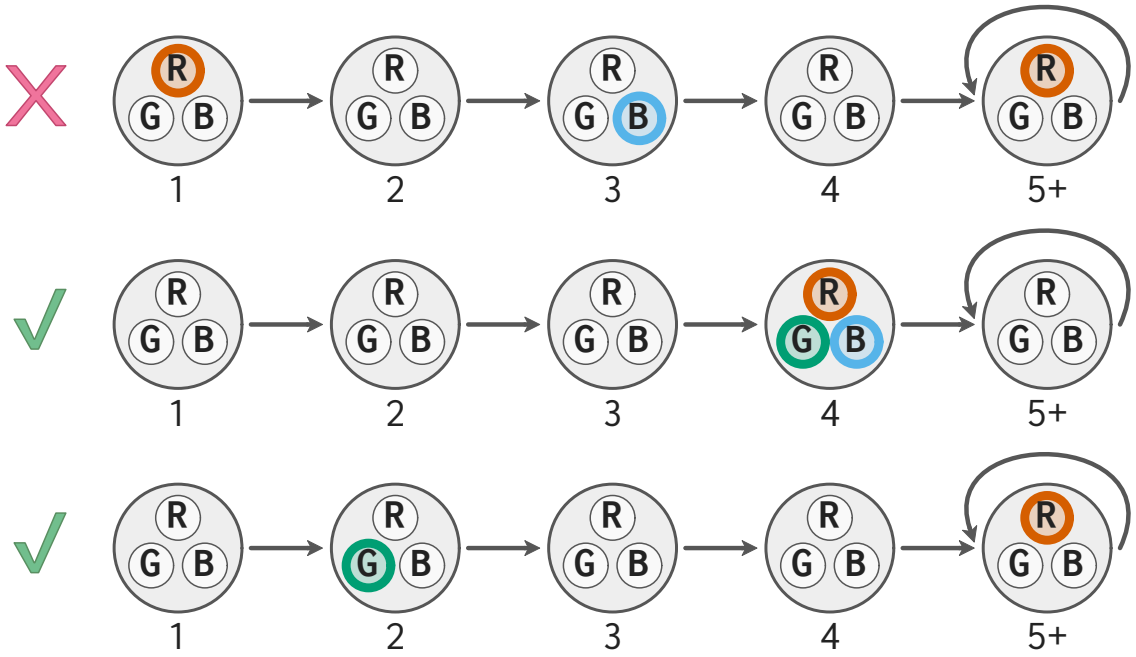

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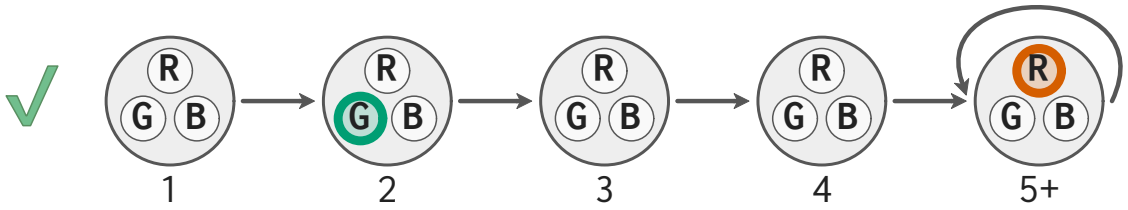
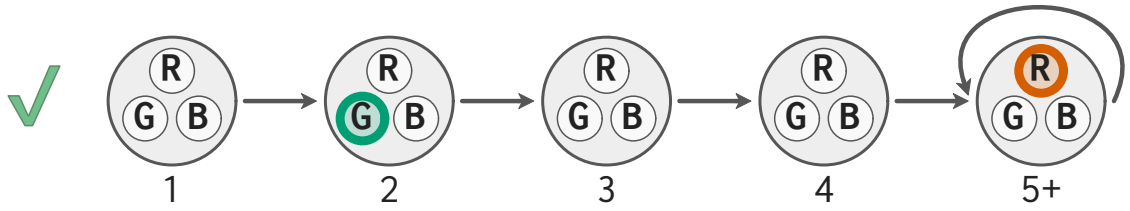


Q. Do the traces below satisfy the formula?

`{eventually Red} and {eventually Green}`

Not satisfied, because Green comes before Red

Bad `Prop` misconception



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Red

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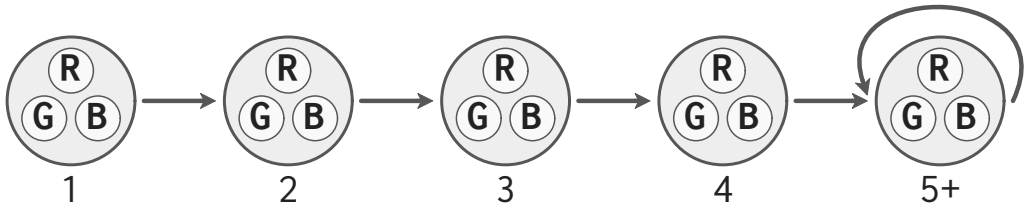

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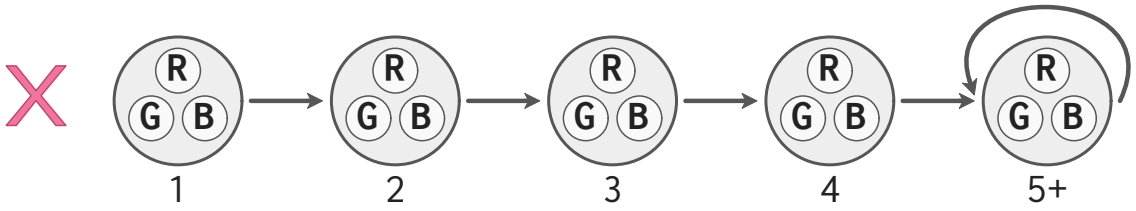

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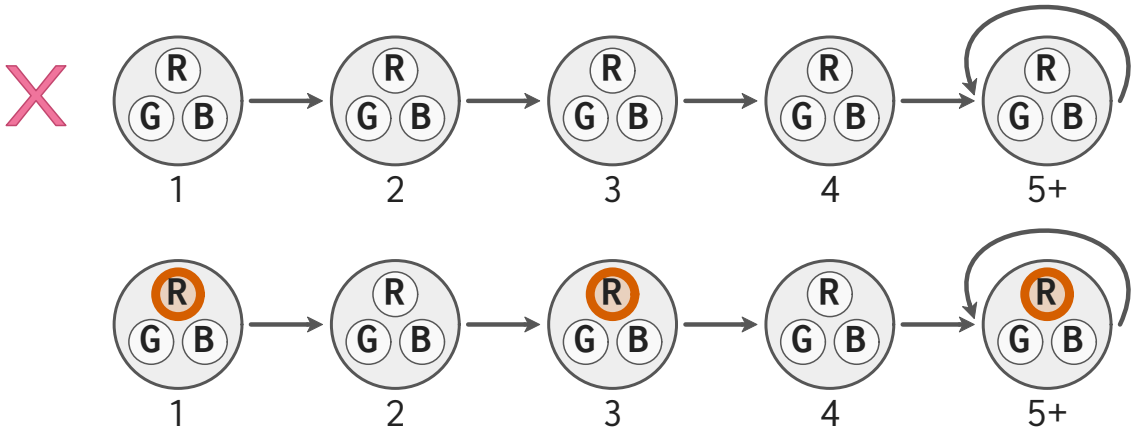

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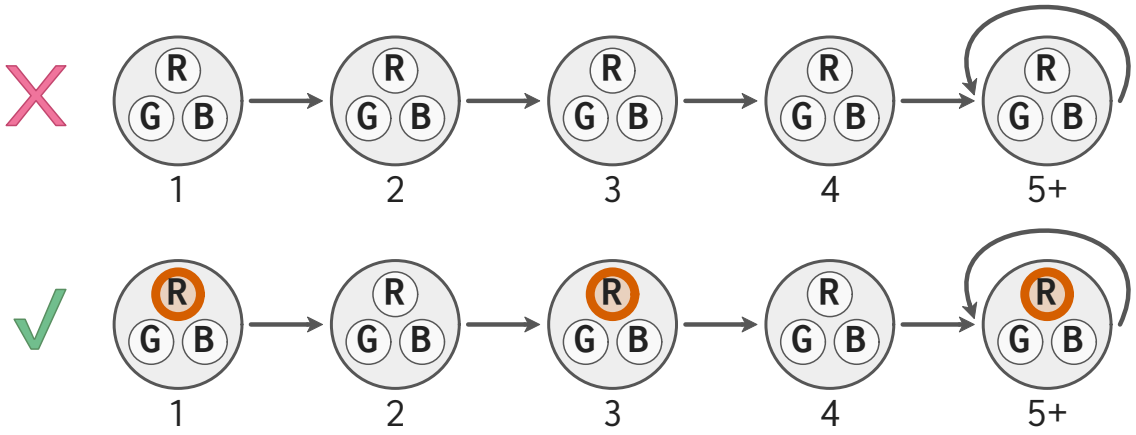

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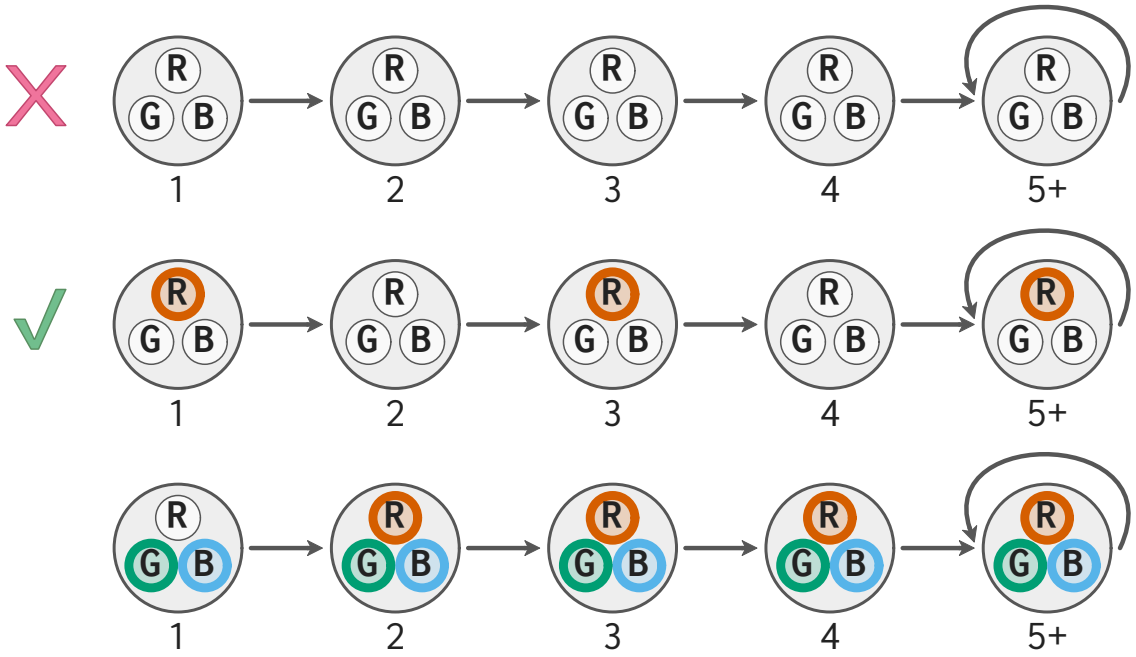

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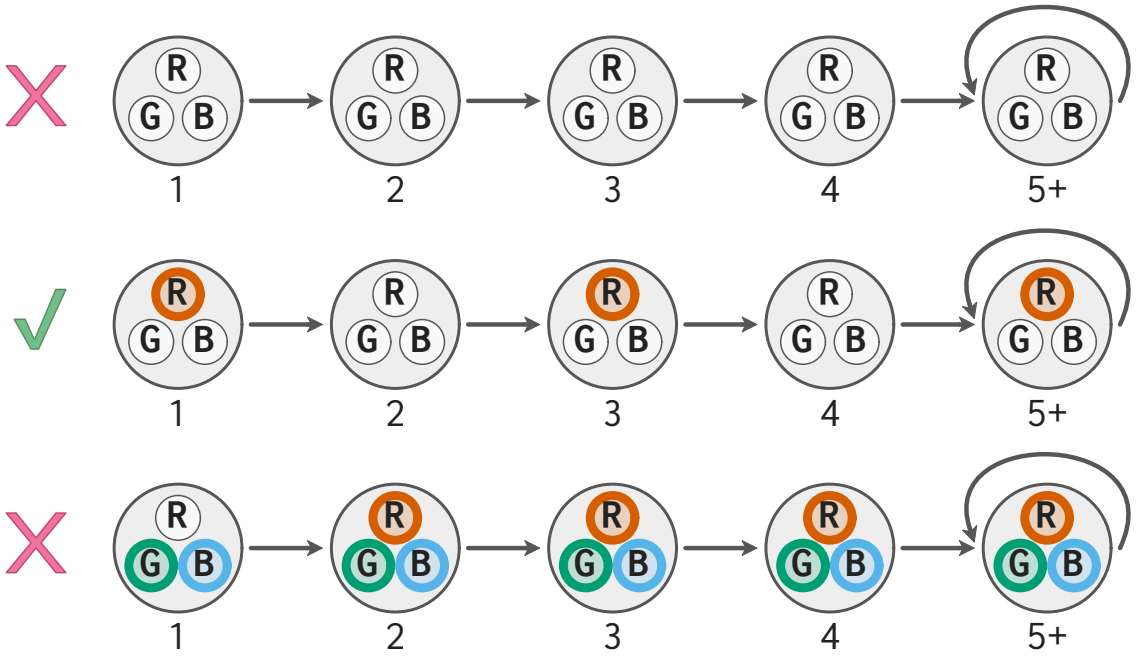

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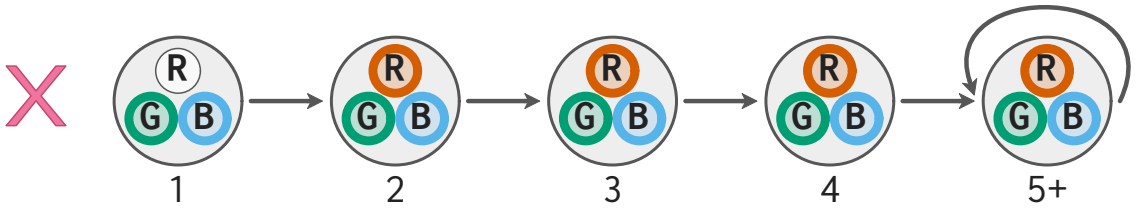
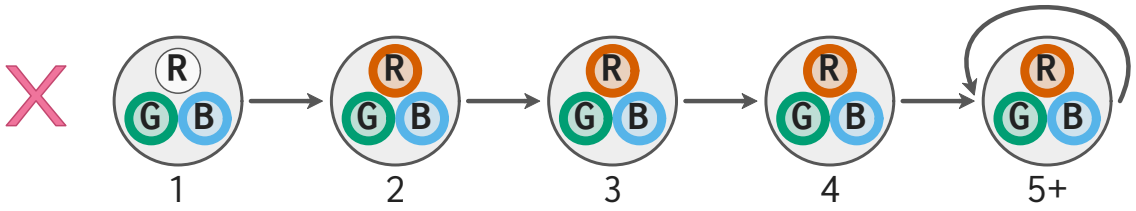


Q. Do the traces below satisfy the formula?

Red

Satisfied because Red is on at some point

`Implicit F` misconception



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`Red until Blue`

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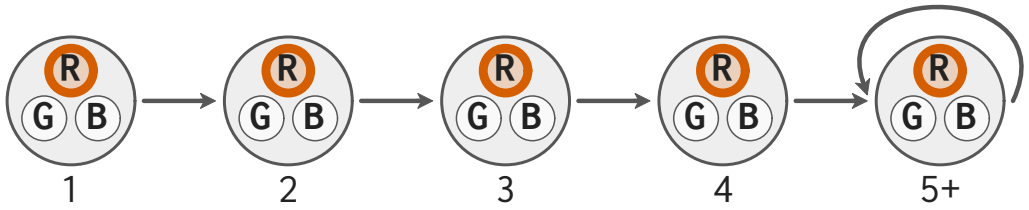

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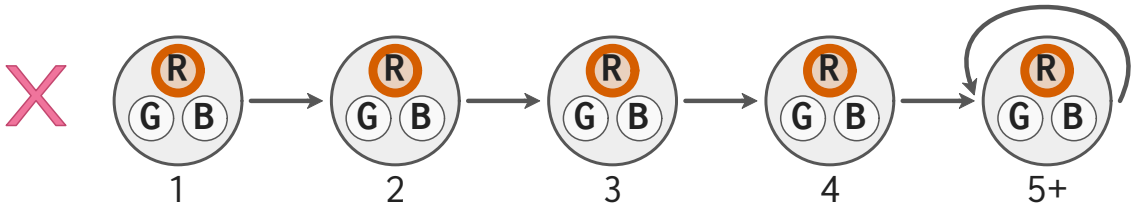

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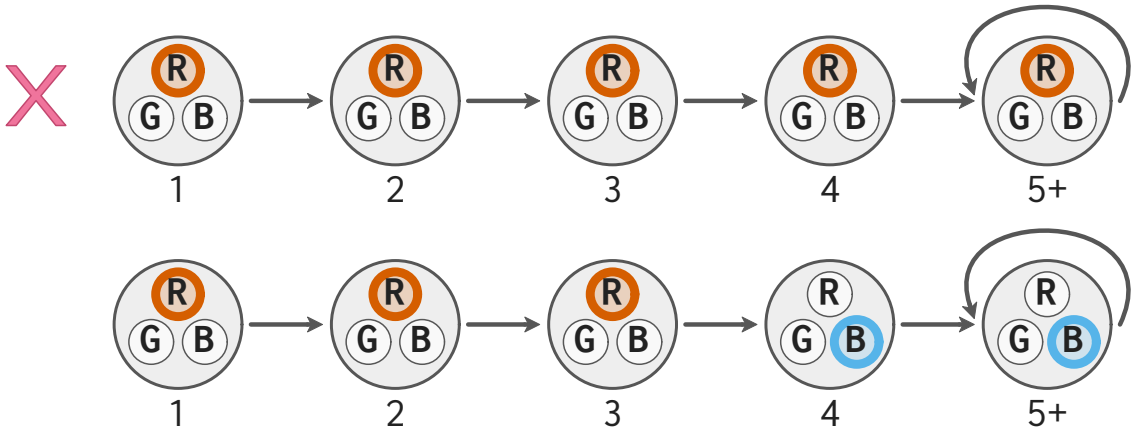

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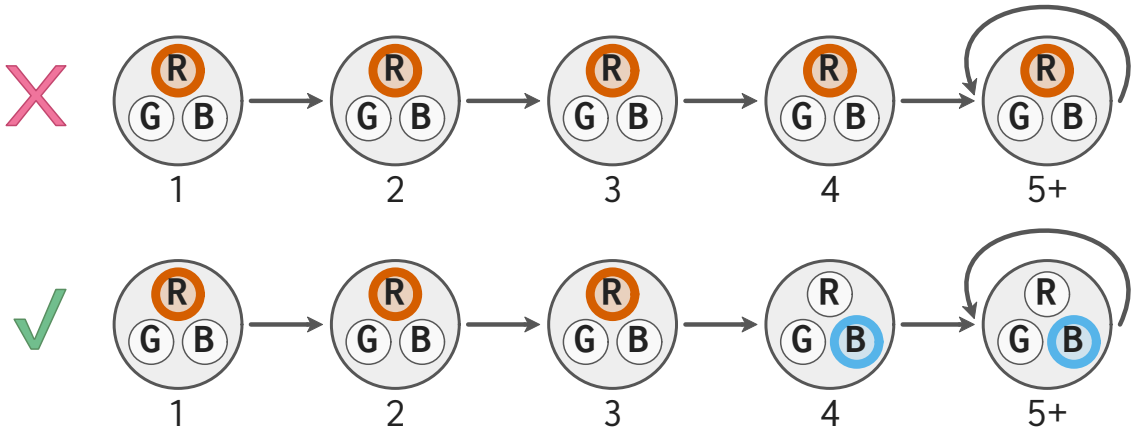

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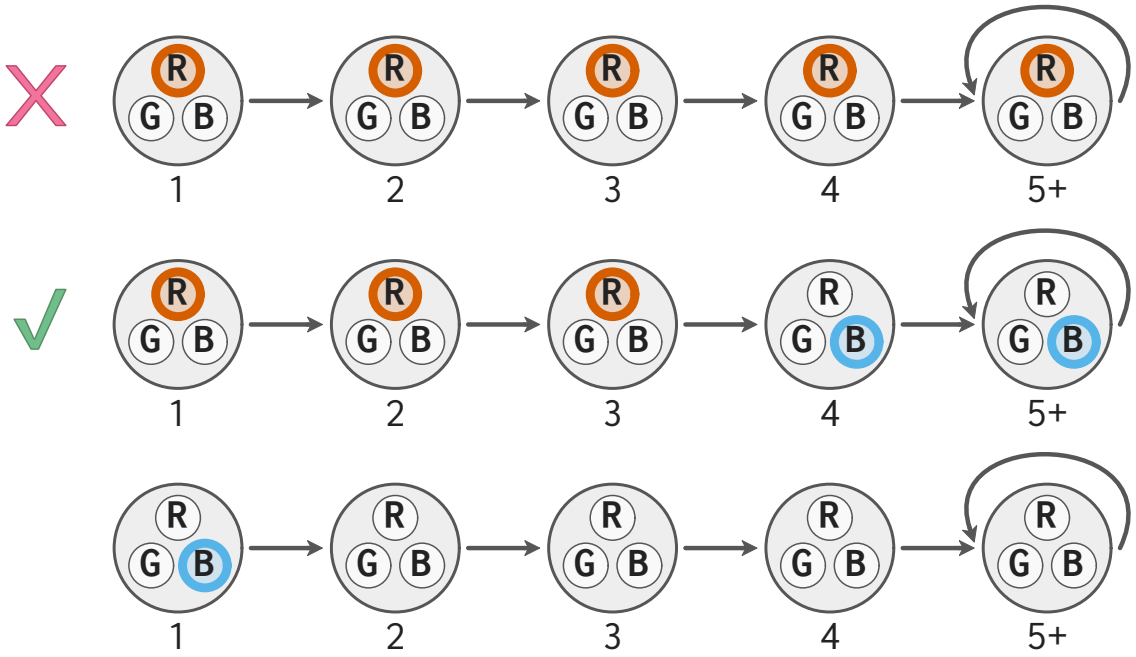

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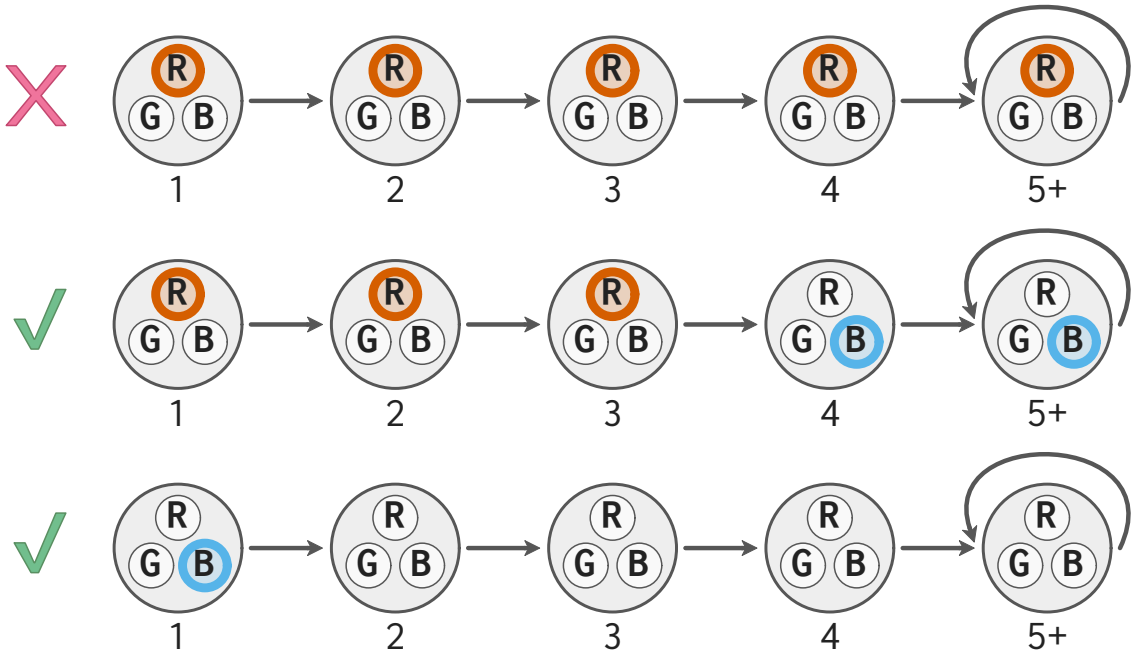

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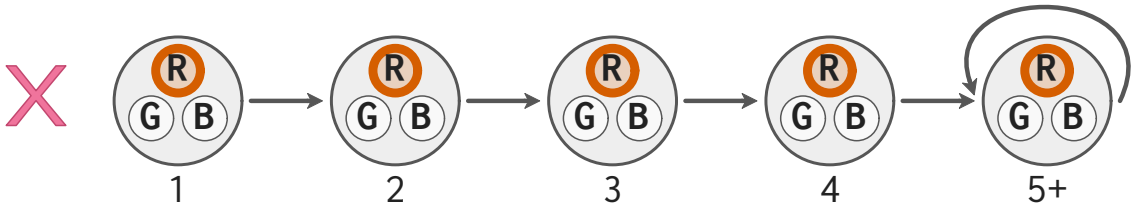

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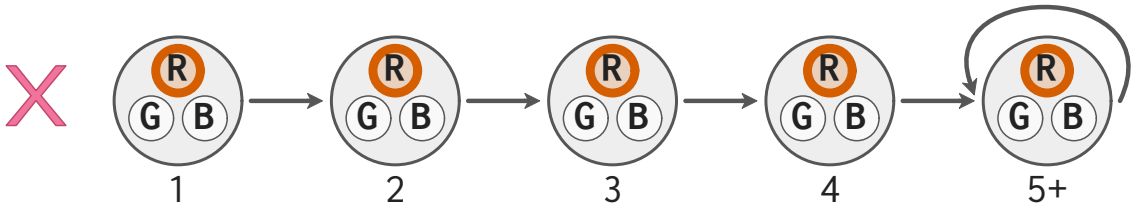

Satisfied because Blue may stay off

Even among researchers!

`Weak U` misconception

Part 2:

LTL to English

Q. Translate to English

{Red until Blue} and {always Red}

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{Red until Blue} and {always Red}

"Red is always on"

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Q. Translate to English

{Red until Blue} and {always Red}

"Red is always on"

"Red is always on and Blue is eventually on"

Q. Translate to English

{Red until Blue} and {always Red}

✗ "Red is always on"

✓ "Red is always on and Blue is eventually on"

Q. Translate to English

{Red until Blue} and {always Red}

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"This statement can never be satisfied"

Q. Translate to English

{Red until Blue} and {always Red}

✗ "Red is always on"

✓ "Red is always on and Blue is eventually on"

✗ "This statement can never be satisfied"

Q. Translate to English

{Red until Blue} and {always Red}

"This statement can never be satisfied"

Q. Translate to English

{Red until Blue} and {always Red}

When Blue turns on, Red **must** be off

`Exclusive U` misconception

✗ "This statement can never be satisfied"

Q. Translate to English

{eventually Red} implies {always Blue}

Q. Translate to English

`{eventually Red} implies {always Blue}`

"if Red is ever on, then Blue is always on"

Q. Translate to English

`{eventually Red} implies {always Blue}`

✓ "if Red is ever on, then Blue is always on"

Q. Translate to English

`{eventually Red} implies {always Blue}`

✓ "if Red is ever on, then Blue is always on"

"Red is on at some point, after which Blue is on"

Q. Translate to English

`{eventually Red} implies {always Blue}`

✓ "if Red is ever on, then Blue is always on"

✗ "Red is on at some point, after which Blue is on"

Q. Translate to English

`{eventually Red} implies {always Blue}`

✗ "Red is on at some point, after which Blue is on"

Q. Translate to English

`{eventually Red} implies {always Blue}`

Red **will** turn on

`Bad Prop` misconception

"Red is on at some point, after which Blue is on"

Part 3:

English to LTL

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

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```
Impossible!
```

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`Impossible!`

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

```
Impossible!
```

```
{eventually Red} and {always {Red => always !Red}}
```

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

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Impossible!
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Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

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Impossible!
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```
{eventually Red} and {always {Red => always !Red}}
```

```
{eventually Red} and {always {Red => after {always !Red}}}
```

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

✗ `Impossible!`

✗ `{eventually Red} and {always {Red => always !Red}}`

✓ `{eventually Red} and {always {Red => after {always !Red}}}`

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

```
{eventually Red} and {always {Red => always !Red}}
```

Q. Translate to LTL

The Red light is on in exactly one state, but not necessarily the first state

An implication constrains the **next state**

`Bad State Index` misconception

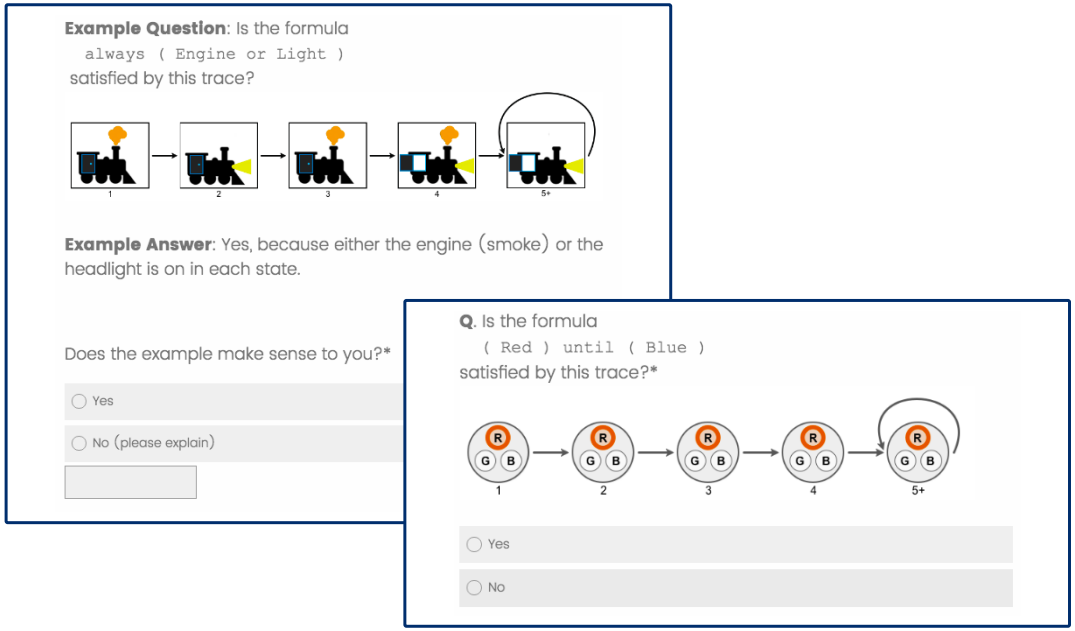
```
{eventually Red} and {always {Red => always !Red}}
```

All Done!

Simple formulas, yet
subtle issues and **expert blind spots**

Quiz Q's Based on 3 Instruments

- LTL to English
- English to LTL
- Trace Satisfaction



cs.brown.edu/~bgreenma/ltl-instruments.pdf

Code Book for Analysis

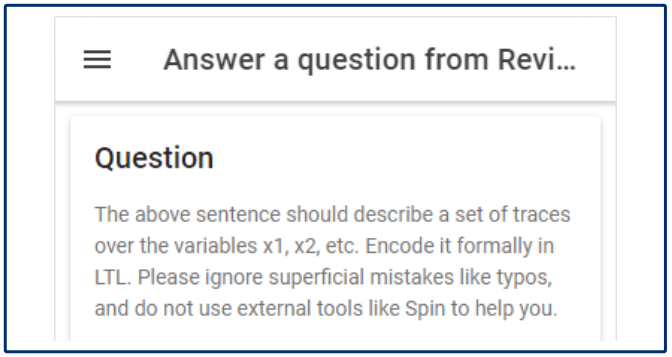
Bad Prop	Implicit F
Bad State Index	Implicit G
Bad State Quantification	Other Implicit
Exclusive U	Weak U

To appear in **Programming 7.2**

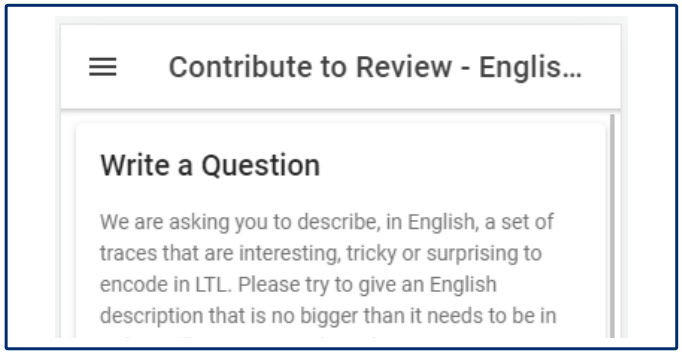
Software: Quizius

Class-sourcing to discover misconceptions

1. Answer Top Q's



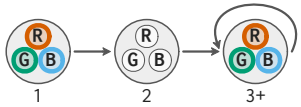
2. Submit New Q's



What Next?

What Next?

1. Teach Better



our instruments can help!

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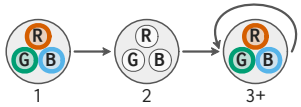

our instruments can help!

... but learners are everywhere
not just in classrooms

amazon Meta

NETFLIX

What Next?

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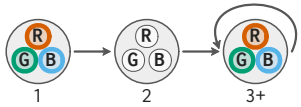

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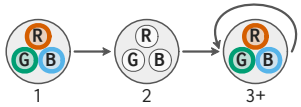

our instruments can help!

2. Build Tools

guard against misconceptions

What Next?

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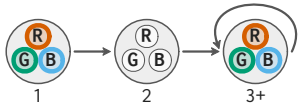

our instruments can help!

2. Build Tools

guard against misconceptions

3. Design Logics

Alloy 6 **Electrum**

our findings have inspired changes

Thank You!

benjamin.l.greenman@gmail.com