# Supplmentary material for "Towards a unified language in experimental designs propagated by a software framework" 

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## Applications

The following code uses the R-package edibble (Tanaka 2023) in the R language ( R Core Team 2020) to construct three types of experimental design described in the main paper. The full design tables for the split-plot design, complex nested design and unbalanced factorial design are shown in Table 1, Table 2 and Table 3, respectively.

```
library(edibble)
```


## Classic Split-Plot Design

The experiment, described in Fisher (1950), is a classic split-plot design for testing the yield of a crop with 12 varieties under 3 different types of fertilizer.

Below we define the unit and treatment factors.

```
des1str <- design("Fisher's split-plot design") %>%
    set_units(patch = 36,
        plot = nested_in(patch, 3)) %>%
    set_trts(variety = 12,
            fertilizer = c("basal", "sulphate", "chloride"))
```

You may also set the responses.

```
des1strr <- des1str %>%
    set_rcrds(yield = plot,
            biomass = patch)
```

At this stage, the design is not complete and stored in the network form.

```
des1strr
```

Fisher's split-plot design
+-patch (36 levels)
| +-plot (108 levels)
| | \-yield
| \-biomass
+-variety (12 levels)
\-fertilizer (3 levels)

We need to specify the relationship between factors. We can then get the design table.

```
des1 <- des1strr %>%
    allot_trts(variety ~ patch,
            fertilizer ~ plot) %>%
    assign_trts(seed = 1,
        order = c("random", "random")) %>%
    serve_table()
```

The output is a special class of data.frame. See Table 1 for the full design table.
des1
\# Fisher's split-plot design
\# An edibble: 108 x 6
patch plot variety fertilizer yield biomass
<unit(36)> <unit(108)> <trt(12)> <trt(3)> <rcrd> <rcrd>
1 patch1 plot1 variety11 sulphate o
2 patch1 plot2 variety11 chloride o x
3 patch1 plot3 variety11 basal o x
4 patch2 plot4 variety9 chloride o
5 patch2 plot5 variety9 sulphate 0 x
6 patch2 plot6 variety9 basal 6

| 7 | patch3 plot7 variety6 sulphate 0 | 0 |
| :--- | :--- | :--- |


| 9 | patch3 | plot9 | variety6 | chloride | 0 | x |
| :---: | :---: | :--- | :--- | :--- | :--- | :--- |
| 10 | patch4 | plot10 | variety2 | basal | 0 | o |
| \# i | 98 | more rows |  |  |  |  |

Table 1: Design table output for the classic split plot design.

| patch | plot | variety | fertilizer | yield | biomass |
| :--- | :--- | :--- | :--- | :--- | :--- |
| patch1 | plot1 | variety11 | sulphate | NA | NA |
| patch1 | plot2 | variety11 | chloride | NA | NA |
| patch1 | plot3 | variety11 | basal | NA | NA |
| patch2 | plot4 | variety9 | chloride | NA | NA |
| patch2 | plot5 | variety9 | sulphate | NA | NA |
| patch2 | plot6 | variety9 | basal | NA | NA |
| patch3 | plot7 | variety6 | sulphate | NA | NA |
| patch3 | plot8 | variety6 | basal | NA | NA |
| patch3 | plot9 | variety6 | chloride | NA | NA |
| patch4 | plot10 | variety2 | basal | NA | NA |
| patch4 | plot11 | variety2 | chloride | NA | NA |
| patch4 | plot12 | variety2 | sulphate | NA | NA |
| patch5 | plot13 | variety5 | basal | NA | NA |
| patch5 | plot14 | variety5 | chloride | NA | NA |
| patch5 | plot15 | variety5 | sulphate | NA | NA |
| patch6 | plot16 | variety5 | sulphate | NA | NA |
| patch6 | plot17 | variety5 | chloride | NA | NA |
| patch6 | plot18 | variety5 | basal | NA | NA |
| patch7 | plot19 | variety8 | basal | NA | NA |
| patch7 | plot20 | variety8 | sulphate | NA | NA |
| patch7 | plot21 | variety8 | chloride | NA | NA |
| patch8 | plot22 | variety10 | chloride | NA | NA |
| patch8 | plot23 | variety10 | sulphate | NA | NA |
| patch8 | plot24 | variety10 | basal | NA | NA |
| patch9 | plot25 | variety1 | basal | NA | NA |
| patch9 | plot26 | variety1 | sulphate | NA | NA |
| patch9 | plot27 | variety1 | chloride | NA | NA |
| patch10 | plot28 | variety3 | chloride | NA | NA |
| patch10 | plot29 | variety3 | sulphate | NA | NA |
| patch10 | plot30 | variety3 | basal | NA | NA |
| patch11 | plot31 | variety3 | chloride | NA | NA |
| patch11 | plot32 | variety3 | basal | NA | NA |
| patch11 | plot33 | variety3 | sulphate | NA | NA |
| patch12 | plot34 | variety8 | basal | NA | NA |
|  | variety8 | sulphate | NA | NA |  |
|  |  |  |  |  |  |


| patch | plot | variety | fertilizer | yield | biomass |
| :---: | :---: | :---: | :---: | :---: | :---: |
| patch12 | plot36 | variety8 | chloride | NA | NA |
| patch13 | plot37 | variety3 | chloride | NA | NA |
| patch13 | plot38 | variety3 | sulphate | NA | NA |
| patch13 | plot39 | variety3 | basal | NA | NA |
| patch14 | plot40 | variety12 | basal | NA | NA |
| patch14 | plot41 | variety12 | sulphate | NA | NA |
| patch14 | plot42 | variety12 | chloride | NA | NA |
| patch15 | plot43 | variety11 | basal | NA | NA |
| patch15 | plot44 | variety11 | sulphate | NA | NA |
| patch15 | plot45 | variety11 | chloride | NA | NA |
| patch16 | plot46 | variety12 | sulphate | NA | NA |
| patch16 | plot47 | variety12 | chloride | NA | NA |
| patch16 | plot48 | variety12 | basal | NA | NA |
| patch17 | plot49 | variety 10 | basal | NA | NA |
| patch17 | plot50 | variety10 | chloride | NA | NA |
| patch17 | plot51 | variety10 | sulphate | NA | NA |
| patch18 | plot52 | variety 4 | basal | NA | NA |
| patch18 | plot53 | variety 4 | chloride | NA | NA |
| patch18 | plot54 | variety4 | sulphate | NA | NA |
| patch19 | plot55 | variety5 | basal | NA | NA |
| patch19 | plot56 | variety5 | chloride | NA | NA |
| patch19 | plot57 | variety5 | sulphate | NA | NA |
| patch20 | plot58 | variety11 | basal | NA | NA |
| patch20 | plot59 | variety11 | chloride | NA | NA |
| patch20 | plot60 | variety11 | sulphate | NA | NA |
| patch21 | plot61 | variety8 | chloride | NA | NA |
| patch21 | plot62 | variety8 | sulphate | NA | NA |
| patch21 | plot63 | variety8 | basal | NA | NA |
| patch22 | plot64 | variety9 | sulphate | NA | NA |
| patch22 | plot65 | variety9 | chloride | NA | NA |
| patch22 | plot66 | variety9 | basal | NA | NA |
| patch23 | plot67 | variety7 | basal | NA | NA |
| patch23 | plot68 | variety7 | chloride | NA | NA |
| patch23 | plot69 | variety7 | sulphate | NA | NA |
| patch24 | plot70 | variety1 | chloride | NA | NA |
| patch24 | plot71 | variety1 | basal | NA | NA |
| patch24 | plot72 | variety1 | sulphate | NA | NA |
| patch25 | plot73 | variety7 | basal | NA | NA |
| patch25 | plot74 | variety7 | chloride | NA | NA |
| patch25 | plot75 | variety7 | sulphate | NA | NA |
| patch26 | plot76 | variety7 | chloride | NA | NA |


| patch | plot | variety | fertilizer | yield | biomass |
| :--- | :--- | :--- | :--- | :--- | :--- |
| patch26 | plot77 | variety7 | basal | NA | NA |
| patch26 | plot78 | variety7 | sulphate | NA | NA |
| patch27 | plot79 | variety2 | basal | NA | NA |
| patch27 | plot80 | variety2 | chloride | NA | NA |
| patch27 | plot81 | variety2 | sulphate | NA | NA |
| patch28 | plot82 | variety12 | basal | NA | NA |
| patch28 | plot83 | variety12 | chloride | NA | NA |
| patch28 | plot84 | variety12 | sulphate | NA | NA |
| patch29 | plot85 | variety4 | basal | NA | NA |
| patch29 | plot86 | variety4 | sulphate | NA | NA |
| patch29 | plot87 | variety4 | chloride | NA | NA |
| patch30 | plot88 | variety4 | chloride | NA | NA |
| patch30 | plot89 | variety4 | basal | NA | NA |
| patch30 | plot90 | variety4 | sulphate | NA | NA |
| patch31 | plot91 | variety9 | sulphate | NA | NA |
| patch31 | plot92 | variety9 | basal | NA | NA |
| patch31 | plot93 | variety9 | chloride | NA | NA |
| patch32 | plot94 | variety6 | chloride | NA | NA |
| patch32 | plot95 | variety6 | sulphate | NA | NA |
| patch32 | plot96 | variety6 | basal | NA | NA |
| patch33 | plot97 | variety1 | sulphate | NA | NA |
| patch33 | plot98 | variety1 | chloride | NA | NA |
| patch33 | plot99 | variety1 | basal | NA | NA |
| patch34 | plot100 | variety2 | basal | NA | NA |
| patch34 | plot101 | variety2 | chloride | NA | NA |
| patch34 | plot102 | variety2 | sulphate | NA | NA |
| patch35 | plot103 | variety10 | sulphate | NA | NA |
| patch35 | plot104 | variety10 | basal | NA | NA |
| patch35 | plot105 | variety10 | chloride | NA | NA |
| patch36 | plot106 | variety6 | sulphate | NA | NA |
| patch36 | plot107 | variety6 | chloride | NA | NA |
| patch36 | plot108 | variety6 | basal | NA | NA |
|  |  |  |  |  |  |

## Alternative unit specification

In the above code, we have specified the units as below.

```
des1unit <- design("Unit specification") %>%
    set_units(patch = 36,
```

```
plot = nested_in(patch, 3))
```

In another instance, you may be told the total number of plots $(36 \times 3=108)$. In this case, it may cognitively make more sense to specify the total number of plots directly as below.

```
des1unitalt <- design("Alternative unit specification") %>%
    set_units(patch = 36,
        plot = 108)
```

The above code does not, however, the relationship between patch and plot. For this, we can use allot_units() to signal the nesting of the units and assign_units() to actually assign the small units to large units as below.

```
des1unitalt %>%
    allot_units(patch ~ plot) %>%
    assign_units("systematic")
```

```
Alternative unit specification
\-patch (36 levels)
    \-plot (108 levels)
Allotment:
```

The above is more verbose than the first approach, however, this may cognitively align with how the units are specified in conversation. Ultimately, it will be user choice on how this is specified, but the end result is essentially the same.

## Complex Nested Design

Consider next the experiment in Martin, Johnson, and Forsyth (1996) aimed to investigate if insecticides used to control grasshoppers affected the weight of young chicks of ring-necked pheasants, either by affecting the grass around the chicks or by affecting the grasshoppers eaten by the chicks.

```
des2 <- design("Complex nested factorial design") %>%
    set_trts(insecticide = 3,
            dose_level = c("low", "high"),
            food_type = c("sprayed", "unsprayed")) %>%
    set_units(week = 3,
            strip = nested_in(week, 3),
            swath = nested_in(strip, 2),
```

```
8 pen = nested_in(swath, 2),
        chick = nested_in(pen, 6)) %>%
allot_trts(insecticide ~ strip,
                        dose_level ~ swath,
        food_type ~ pen) %>%
assign_trts(seed = 1) %>%
serve_table()
```

Table 2: Design table output for the complex nested design.

| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick1 |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick2 |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick3 |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick4 |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick5 |
| insecticide2 | high | unsprayed | week1 | strip1 | swath1 | pen1 | chick6 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick7 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick8 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick9 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick10 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick11 |
| insecticide2 | high | sprayed | week1 | strip1 | swath1 | pen2 | chick12 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick13 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick14 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick15 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick16 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick17 |
| insecticide2 | low | unsprayed | week1 | strip1 | swath2 | pen3 | chick18 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick19 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick20 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick21 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick22 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick23 |
| insecticide2 | low | sprayed | week1 | strip1 | swath2 | pen4 | chick24 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick25 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick26 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick27 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick28 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick29 |
| insecticide3 | high | sprayed | week1 | strip2 | swath3 | pen5 | chick30 |


| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick31 |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick32 |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick33 |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick34 |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick35 |
| insecticide3 | high | unsprayed | week1 | strip2 | swath3 | pen6 | chick36 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick37 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick38 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick39 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick40 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick41 |
| insecticide3 | low | unsprayed | week1 | strip2 | swath4 | pen7 | chick42 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick43 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick44 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick45 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick46 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick47 |
| insecticide3 | low | sprayed | week1 | strip2 | swath4 | pen8 | chick48 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick49 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick50 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick51 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick52 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick53 |
| insecticide1 | high | sprayed | week1 | strip3 | swath5 | pen9 | chick54 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick55 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick56 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick57 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick58 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick59 |
| insecticide1 | high | unsprayed | week1 | strip3 | swath5 | pen10 | chick60 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick61 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick62 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick63 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick64 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick65 |
| insecticide1 | low | unsprayed | week1 | strip3 | swath6 | pen11 | chick66 |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick67 |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick68 |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick69 |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick70 |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick71 |


| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| insecticide1 | low | sprayed | week1 | strip3 | swath6 | pen12 | chick72 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick73 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick74 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick75 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick76 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick77 |
| insecticide3 | low | unsprayed | week2 | strip4 | swath7 | pen13 | chick78 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick79 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick80 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick81 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick82 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick83 |
| insecticide3 | low | sprayed | week2 | strip4 | swath7 | pen14 | chick84 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick85 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick86 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick87 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick88 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick89 |
| insecticide3 | high | sprayed | week2 | strip4 | swath8 | pen15 | chick90 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick91 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick92 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick93 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick94 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick95 |
| insecticide3 | high | unsprayed | week2 | strip4 | swath8 | pen16 | chick96 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick97 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick98 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick99 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick100 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick101 |
| insecticide1 | high | sprayed | week2 | strip5 | swath9 | pen17 | chick102 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick103 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick104 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick105 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick106 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick107 |
| insecticide1 | high | unsprayed | week2 | strip5 | swath9 | pen18 | chick108 |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick109 |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick110 |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick111 |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick112 |


| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick113 |
| insecticide1 | low | unsprayed | week2 | strip5 | swath10 | pen19 | chick114 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick115 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick116 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick117 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick118 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick119 |
| insecticide1 | low | sprayed | week2 | strip5 | swath10 | pen20 | chick120 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick121 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick122 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick123 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick124 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick125 |
| insecticide2 | low | unsprayed | week2 | strip6 | swath11 | pen21 | chick126 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick127 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick128 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick129 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick130 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick131 |
| insecticide2 | low | sprayed | week2 | strip6 | swath11 | pen22 | chick132 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick133 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick134 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick135 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick136 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick137 |
| insecticide2 | high | sprayed | week2 | strip6 | swath12 | pen23 | chick138 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick139 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick140 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick141 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick142 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick143 |
| insecticide2 | high | unsprayed | week2 | strip6 | swath12 | pen24 | chick144 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick145 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick146 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick147 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick148 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick149 |
| insecticide3 | high | unsprayed | week3 | strip7 | swath13 | pen25 | chick150 |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick151 |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick152 |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick153 |


| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick154 |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick155 |
| insecticide3 | high | sprayed | week3 | strip7 | swath13 | pen26 | chick156 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick157 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick158 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick159 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick160 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick161 |
| insecticide3 | low | unsprayed | week3 | strip7 | swath14 | pen27 | chick162 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick163 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick164 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick165 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick166 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick167 |
| insecticide3 | low | sprayed | week3 | strip7 | swath14 | pen28 | chick168 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick169 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick170 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick171 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick172 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick173 |
| insecticide2 | low | unsprayed | week3 | strip8 | swath15 | pen29 | chick174 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick175 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick176 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick177 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick178 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick179 |
| insecticide2 | low | sprayed | week3 | strip8 | swath15 | pen30 | chick180 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick181 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick182 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick183 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick184 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick185 |
| insecticide2 | high | sprayed | week3 | strip8 | swath16 | pen31 | chick186 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick187 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick188 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick189 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick190 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick191 |
| insecticide2 | high | unsprayed | week3 | strip8 | swath16 | pen32 | chick192 |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick193 |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick194 |


| insecticide | dose_level | food_type | week | strip | swath | pen | chick |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick195 |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick196 |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick197 |
| insecticide1 | high | sprayed | week3 | strip9 | swath17 | pen33 | chick198 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick199 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick200 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick201 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick202 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick203 |
| insecticide1 | high | unsprayed | week3 | strip9 | swath17 | pen34 | chick204 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick205 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick206 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick207 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick208 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick209 |
| insecticide1 | low | sprayed | week3 | strip9 | swath18 | pen35 | chick210 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick211 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick212 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick213 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick214 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick215 |
| insecticide1 | low | unsprayed | week3 | strip9 | swath18 | pen36 | chick216 |

## Unbalanced Factorial Design

Here we consider the first four motion sickness experiments reported in Burns (1984).

```
des3 <- design("Motion sickness incidence") %>%
    set_units(experiment = 4,
            subject = nested_in(experiment,
                1 ~ 21,
                2 ~ 20,
                3 ~ 29,
                        4 ~ 59)) %>%
    set_trts(frequency = c(0.167, 0.250),
            acceleration = c(0.111, 0.222)) %>%
    allot_trts(frequency:acceleration ~ experiment) %>%
    assign_trts(order = "systematic") %>%
    serve_table()
```

Table 3: Design table output for the unbalanced factorial design.

| experiment | subject | frequency | acceleration |
| :--- | :--- | :--- | :--- |
| experiment1 | subject1 | 0.167 | 0.111 |
| experiment1 | subject2 | 0.167 | 0.111 |
| experiment1 | subject3 | 0.167 | 0.111 |
| experiment1 | subject4 | 0.167 | 0.111 |
| experiment1 | subject5 | 0.167 | 0.111 |
| experiment1 | subject6 | 0.167 | 0.111 |
| experiment1 | subject7 | 0.167 | 0.111 |
| experiment1 | subject8 | 0.167 | 0.111 |
| experiment1 | subject9 | 0.167 | 0.111 |
| experiment1 | subject10 | 0.167 | 0.111 |
| experiment1 | subject11 | 0.167 | 0.111 |
| experiment1 | subject12 | 0.167 | 0.111 |
| experiment1 | subject13 | 0.167 | 0.111 |
| experiment1 | subject14 | 0.167 | 0.111 |
| experiment1 | subject15 | 0.167 | 0.111 |
| experiment1 | subject16 | 0.167 | 0.111 |
| experiment1 | subject17 | 0.167 | 0.111 |
| experiment1 | subject18 | 0.167 | 0.111 |
| experiment1 | subject19 | 0.167 | 0.111 |
| experiment1 | subject20 | 0.167 | 0.111 |
| experiment1 | subject21 | 0.167 | 0.111 |
| experiment2 | subject22 | 0.25 | 0.111 |
| experiment2 | subject23 | 0.25 | 0.111 |
| experiment2 | subject24 | 0.25 | 0.111 |
| experiment2 | subject25 | 0.25 | 0.111 |
| experiment2 | subject26 | 0.25 | 0.111 |
| experiment2 | subject27 | 0.25 | 0.111 |
| experiment2 | subject28 | 0.25 | 0.111 |
| experiment2 | subject29 | 0.25 | 0.111 |
| experiment2 | subject30 | 0.25 | 0.111 |
| experiment2 | subject31 | 0.25 | 0.111 |
| experiment2 | subject32 | 0.25 | 0.111 |
| experiment2 | subject33 | 0.25 | 0.111 |
| experiment2 | subject34 | 0.25 | 0.111 |
| experiment2 | subject35 | 0.25 | 0.111 |
| experiment2 | subject36 | 0.25 | 0.111 |
| experiment2 | subject37 | 0.25 | 0.111 |
| experiment2 | subject38 | 0.25 | 0.111 |
| experiment2 | subject39 | 0.25 | 0.111 |
|  |  |  |  |


| experiment | subject | frequency | acceleration |
| :--- | :--- | :--- | :--- |
| experiment2 | subject40 | 0.25 | 0.111 |
| experiment2 | subject41 | 0.25 | 0.111 |
| experiment3 | subject42 | 0.167 | 0.222 |
| experiment3 | subject43 | 0.167 | 0.222 |
| experiment3 | subject44 | 0.167 | 0.222 |
| experiment3 | subject45 | 0.167 | 0.222 |
| experiment3 | subject46 | 0.167 | 0.222 |
| experiment3 | subject47 | 0.167 | 0.222 |
| experiment3 | subject48 | 0.167 | 0.222 |
| experiment3 | subject49 | 0.167 | 0.222 |
| experiment3 | subject50 | 0.167 | 0.222 |
| experiment3 | subject51 | 0.167 | 0.222 |
| experiment3 | subject52 | 0.167 | 0.222 |
| experiment3 | subject53 | 0.167 | 0.222 |
| experiment3 | subject54 | 0.167 | 0.222 |
| experiment3 | subject55 | 0.167 | 0.222 |
| experiment3 | subject56 | 0.167 | 0.222 |
| experiment3 | subject57 | 0.167 | 0.222 |
| experiment3 | subject58 | 0.167 | 0.222 |
| experiment3 | subject59 | 0.167 | 0.222 |
| experiment3 | subject60 | 0.167 | 0.222 |
| experiment3 | subject61 | 0.167 | 0.222 |
| experiment3 | subject62 | 0.167 | 0.222 |
| experiment3 | subject63 | 0.167 | 0.222 |
| experiment3 | subject64 | 0.167 | 0.222 |
| experiment3 | subject65 | 0.167 | 0.222 |
| experiment3 | subject66 | 0.167 | 0.222 |
| experiment3 | subject67 | 0.167 | 0.222 |
| experiment3 | subject68 | 0.167 | 0.222 |
| experiment3 | subject69 | 0.167 | 0.222 |
| experiment3 | subject70 | 0.167 | 0.222 |
| experiment4 | subject71 | 0.25 | 0.222 |
| experiment4 | subject72 | 0.25 | 0.222 |
| experiment4 | subject73 | 0.25 | 0.222 |
| experiment4 | subject74 | 0.25 | 0.222 |
| experiment4 | subject75 | 0.25 | 0.222 |
| experiment4 | subject76 | 0.25 | 0.222 |
| experiment4 | subject77 | 0.25 | 0.222 |
| experiment4 | subject78 | 0.25 | 0.222 |
| experiment4 | subject79 | 0.25 | 0.222 |
| experiment4 | subject80 | 0.25 | 0.222 |
|  |  |  |  |
| en |  |  |  |


| experiment | subject | frequency | acceleration |
| :--- | :--- | :--- | :--- |
| experiment4 | subject81 | 0.25 | 0.222 |
| experiment4 | subject82 | 0.25 | 0.222 |
| experiment4 | subject83 | 0.25 | 0.222 |
| experiment4 | subject84 | 0.25 | 0.222 |
| experiment4 | subject85 | 0.25 | 0.222 |
| experiment4 | subject86 | 0.25 | 0.222 |
| experiment4 | subject87 | 0.25 | 0.222 |
| experiment4 | subject88 | 0.25 | 0.222 |
| experiment4 | subject89 | 0.25 | 0.222 |
| experiment4 | subject90 | 0.25 | 0.222 |
| experiment4 | subject91 | 0.25 | 0.222 |
| experiment4 | subject92 | 0.25 | 0.222 |
| experiment4 | subject93 | 0.25 | 0.222 |
| experiment4 | subject94 | 0.25 | 0.222 |
| experiment4 | subject95 | 0.25 | 0.222 |
| experiment4 | subject96 | 0.25 | 0.222 |
| experiment4 | subject97 | 0.25 | 0.222 |
| experiment4 | subject98 | 0.25 | 0.222 |
| experiment4 | subject99 | 0.25 | 0.222 |
| experiment4 | subject100 | 0.25 | 0.222 |
| experiment4 | subject101 | 0.25 | 0.222 |
| experiment4 | subject102 | 0.25 | 0.222 |
| experiment4 | subject103 | 0.25 | 0.222 |
| experiment4 | subject104 | 0.25 | 0.222 |
| experiment4 | subject105 | 0.25 | 0.222 |
| experiment4 | subject106 | 0.25 | 0.222 |
| experiment4 | subject107 | 0.25 | 0.222 |
| experiment4 | subject108 | 0.25 | 0.222 |
| experiment4 | subject109 | 0.25 | 0.222 |
| experiment4 | subject110 | 0.25 | 0.222 |
| experiment4 | subject111 | 0.25 | 0.222 |
| experiment4 | subject112 | 0.25 | 0.222 |
| experiment4 | subject113 | 0.25 | 0.222 |
| experiment4 | subject114 | 0.25 | 0.222 |
| experiment4 | subject115 | 0.25 | 0.222 |
| experiment4 | subject116 | 0.25 | 0.222 |
| experiment4 | subject117 | 0.25 | 0.222 |
| experiment4 | subject118 | 0.25 | 0.222 |
| experiment4 | subject119 | 0.25 | 0.222 |
| experiment4 | subject120 | 0.25 | 0.222 |
| experiment4 | subject121 | 0.25 | 0.222 |
|  |  |  |  |
| ex |  |  |  |


| experiment | subject | frequency | acceleration |
| :--- | :--- | :--- | :--- |
| experiment4 | subject122 | 0.25 | 0.222 |
| experiment4 | subject123 | 0.25 | 0.222 |
| experiment4 | subject124 | 0.25 | 0.222 |
| experiment4 | subject125 | 0.25 | 0.222 |
| experiment4 | subject126 | 0.25 | 0.222 |
| experiment4 | subject127 | 0.25 | 0.222 |
| experiment4 | subject128 | 0.25 | 0.222 |
| experiment4 | subject129 | 0.25 | 0.222 |

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## References

Burns, K. C. 1984. "Motion Sickness Incidence: Distribution of Time to First Emesis and Comparison of Some Complex Motion Conditions." Aviation, Space, and Environmental Medicine 55 (6): 521-27.
Fisher, Ronald A. 1950. Statistical Methods for Research Workers. 11th ed. Oliver and Boyd.
Martin, Pamela A., Daniel L. Johnson, and Douglas J. Forsyth. 1996. "Effects of GrasshopperControl Insecticides on Survival and Brain Acetylcholinesterase of Pheasant ( Phasianus Colchicus ) Chicks." Environmental Toxicology and Chemistry / SETAC 15 (4): 518-24. https://doi.org/10.1897/1551-5028(1996)015\<0518:EOGCIO\>2.3.CO;2.
R Core Team. 2020. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.
Tanaka, Emi. 2023. edibble: Designing Comparative Experiments. https://CRAN.R-project. org/package=edibble.
Xie, Yihui. 2015. Dynamic Documents with $R$ and Knitr. 2nd ed. Boca Raton, Florida: Chapman; Hall/CRC. https://yihui.org/knitr/.
Xie, Yihui, J. J. Allaire, and Garrett Grolemund. 2018. R Markdown: The Definitive Guide. Boca Raton, Florida: Chapman; Hall/CRC. https://bookdown.org/yihui/rmarkdown.

