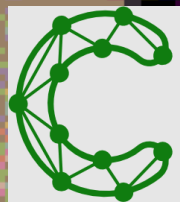# Project Yellow – Bringing Data Types and Functional Programming to Excel

Virtual Master Class – Andy Gordon
Senior Principal Research Manager
Microsoft Research

London Tech Centre – JPMorgan Chase
April 28, 2020

Future of Work
Calc Intelligence

*Transforming the world through deep research*

# Project Yellow

Excel as a Programming Language
A long-term partnership between Excel and MSR Cambridge

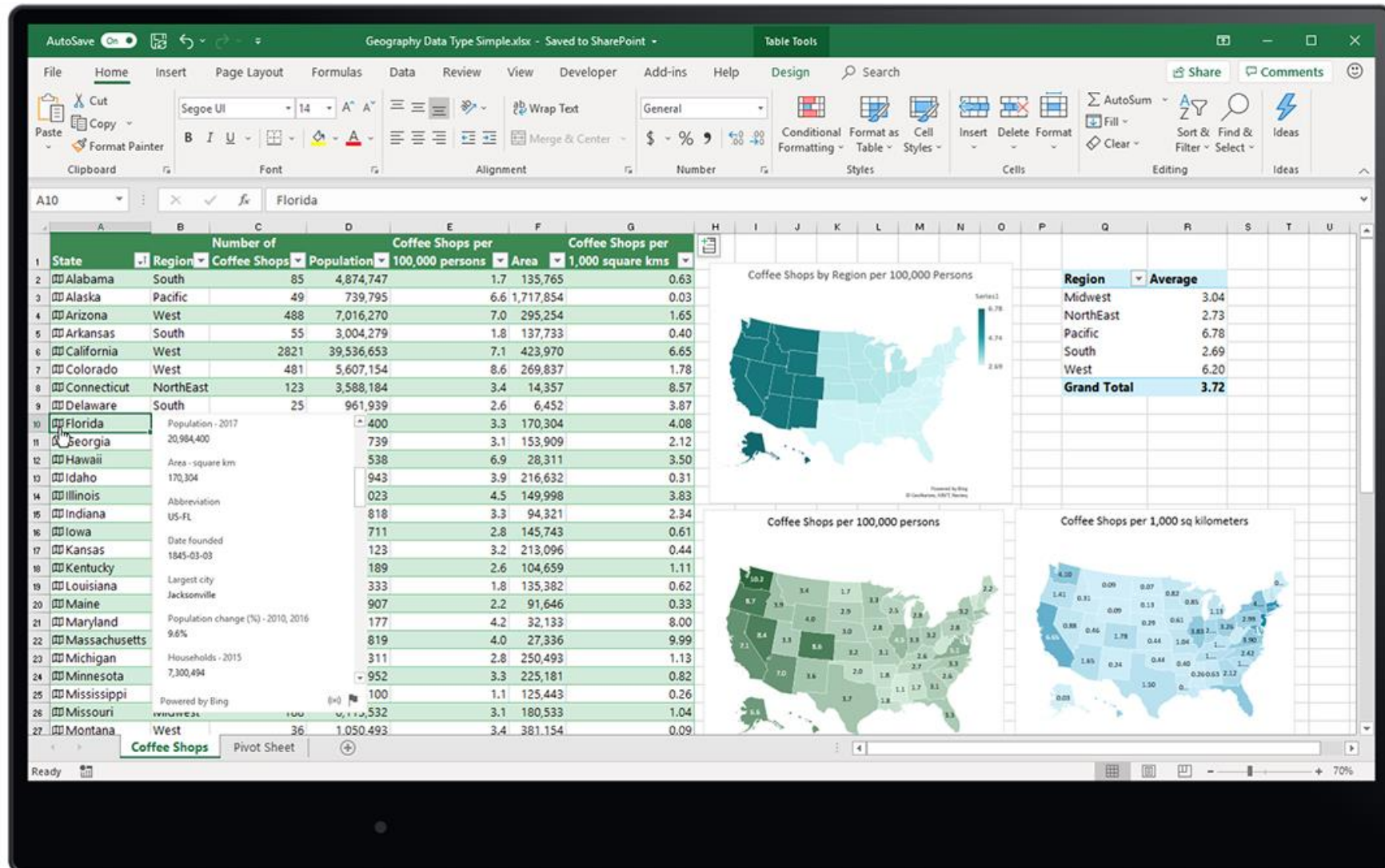Presented by Andy Gordon, MSR Cambridge – adg@microsoft.com

Microsoft Research
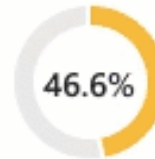
Office

# Aim

Remove the "glass ceiling" that limits the scope and reach of what a domain expert can do with Excel:

- **Make Excel functions reflect the abstractions of our end users**, by allowing end-users to define new functions using an ordinary worksheet.

- **Make Excel's data values reflect the datatypes of our end users' domains**, by adding arrays, vectors, records, and even domain-specific data types implemented by third parties.

# So far, we've taken Excel beyond text and numbers

# So far, we've taken Excel beyond text and numbers

Nutrition - Saved

Insert  Page Layout  Formulas  Data  Review  View  Help

🍎 Gloria's Food        🧑 Daily Goals

#MondayMotivation

Keeping up with my nutrition
goals = #livingmybestlife

32.1%    24.4%    46.6%

| | Calories | Carbohydrates | Fat |
|---|---|---|---|
| Today | 641.4 cal | 61.1g | 23.3g |
| Goal | 2000 | 250 | 50 |

My food 👇

| food | calories | carbohydrates | fat |
|---|---|---|---|
| 🍎 chicken breast | 110.04 | 1.00 | 2.29 |
| 🍎 boiled egg (1 serving) | 210.80 | 1.52 | 14.43 |
| 🍎 strawberry (4 items) | 15.10 | 3.78 | 0.10 |
| 🍎 banana (1 item) | 105.02 | 26.95 | 0.39 |
| 🍎 oatmeal cookie (2 items) | 134.10 | 19.92 | 5.37 |
| 🍎 yogurt (3 ounces) | 66.34 | 7.94 | 0.75 |

**Joe McDaid**
@jjmcdaid

Starting today, the LET function is available to Excel users in the Insiders Ring to preview. The LET function allows you to define and use formula scoped names. Calculating a weighted average: =LET(values,A1:A4, weights,B1:B4, SUM(values*weights)/SUM(weights)) 💡

6:16 PM · Mar 17, 2020 · Twitter Web App

28 Retweets    93 Likes

---

**David Benaim MVP** @DaveBenaim · Mar
Replying to @jjmcdaid
Let it be!

💬          ♡ 3

---

**Exceljet** @exceljet · Mar 17
Replying to @jjmcdaid
Excellent. This will really streamline certain formulas that require the same operation more than 1x.

💬          ♡ 2

---

**Ryan Bond** @RyNBond · Mar 17
Replying to @jjmcdaid
This is similar to 'With' in Power Apps

💬          ♡ 1

---

**Ed Hansberry** @ehansalytics · Mar 18
Replying to @jjmcdaid
Now we just need to be able to format formulas easier in Excel like we can in #PowerBI and #PowerApps

💬          ♡ 1

---

**Abiola David | Excel MVP** 🇳🇬 🌍🏆🥇 @AbiolaDavid01 · Mar 17
Replying to @jjmcdaid
Really cool function

💬 1          ♡ 1

---

**Reagan Onyango** @rigs12 · 18h
Now even before I breathe xlookup, the real bomb is here!

💬          ♡

---

**Oz du Soleil** @OzExcel · Mar 18
Replying to @jjmcdaid
So cool!

💬          ♡

# Calculation View

What if we offered a code-centric view of the grid?

File   Home   Insert   Draw   Page Layout   Formulas   Data   Review   View   Developer   Add-ins   LOAD TEST   Team   Tell me what you want to do   Share

Insert Function   AutoSum   Recently Used   Financial   Logical   Text   Date & Time   Lookup & Reference   Math & Trig   More Functions   | Name Manager   Define Name   Use in Formula   Create from Selection   | Trace Precedents   Trace Dependents   Remove Arrows   Show Formulas   Error Checking   Evaluate Formula   | Watch Window   Calculation Options   Calculate Now   Calculate Sheet

Function Library    Defined Names    Formula Auditing    Calculation

Depreciation    =99%

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Depreciation | 99% | | | HoldingCost | 0.10% | | | | |
| 2 | Assets | Present value | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| 3 | Terminal with Electronic Components | £ 2,728.17 | £ 2,698.16 | £ 2,668.48 | £ 2,639.13 | £ 2,610.10 | £ 2,581.39 | £ 2,552.99 | £ 2,524.91 | £ 2,497 |
| 4 | Accessories Others | £ 196.77 | £ 194.61 | £ 192.46 | £ 190.35 | £ 188.25 | £ 186.18 | £ 184.14 | £ 182.11 | £ 180.11 |
| 5 | Accessories SAK | £ 10.32 | £ 10.21 | £ 10.09 | £ 9.98 | £ 9.87 | £ 9.76 | £ 9.66 | £ 9.55 | £ 9.45 |
| 6 | Accessories SAK | £ 38.28 | £ 37.86 | £ 37.44 | £ 37.03 | £ 36.62 | £ 36.22 | £ 35.82 | £ 35.43 | £ 35.04 |
| 7 | Other Terminals | £ 388.88 | £ 384.60 | £ 380.37 | £ 376.19 | £ 372.05 | £ 367.96 | £ 363.91 | £ 359.91 | £ 355.95 |
| 8 | SAK-Series | £ 430.48 | £ 425.7 | £ 421.06 | £ 416.84 | £ 412.66 | £ 408.52 | £ 404.43 | £ 400.38 | £ 394.02 |
| 9 | SAK-Series | £ 731.01 | £ 722.97 | £ 715.02 | £ 707.16 | £ 699.37 | £ 691.68 | £ 684.07 | £ 676.55 | £ 669.10 |
| 10 | SAK-Series | £ 423.61 | £ 418.95 | £ 414.34 | £ 409.78 | £ 405.28 | £ 400.82 | £ 396.41 | £ 392.05 | £ 387.74 |
| 11 | SAK-Series | £ 397.49 | £ 393.12 | £ 388.79 | £ 384.52 | £ 380.29 | £ 376.10 | £ 371.97 | £ 367.87 | £ 363.83 |
| 12 | SAK-Series | £ 321.88 | £ 318.34 | £ 314.84 | £ 311.37 | £ 307.95 | £ 304.56 | £ 301.21 | £ 297.90 | £ 294.62 |
| 13 | SAK-Series | £ 660.61 | £ 653.34 | £ 646.15 | £ 639.04 | £ 632.02 | £ 625.07 | £ 618.19 | £ 611.39 | £ 604.67 |
| 14 | SAK-Series | £ 748.58 | £ 740.35 | £ 732.20 | £ 724.15 | £ 716.18 | £ 708.30 | £ 700.51 | £ 692.81 | £ 685.19 |
| 15 | Coupler | £ 53.97 | £ 53.38 | £ 52.79 | £ 52.21 | £ 51.63 | £ 51.07 | £ 50.50 | £ 49.95 | £ 49.40 |
| 16 | SAK-Series | £ 356.36 | £ 352.44 | £ 348.56 | £ 344.73 | £ 340.94 | £ 337.19 | £ 333.48 | £ 329.81 | £ 326.18 |
| 17 | SAK-Series | £ 362.18 | £ 358.20 | £ 354.26 | £ 350.36 | £ 346.51 | £ 342.69 | £ 338.92 | £ 335.20 | £ 331.51 |
| 18 | Coupler | £ 49.81 | £ 49.26 | £ 48.72 | £ 48.18 | £ 47.65 | £ 47.13 | £ 46.61 | £ 46.10 | £ 45.59 |
| 19 | SAK-Series | £ 229.38 | £ 226.86 | £ 224.36 | £ 221.89 | £ 219.45 | £ 217.04 | £ 214.65 | £ 212.29 | £ 209.95 |
| 20 | SAK-Series | £ 155.25 | £ 153.54 | £ 151.85 | £ 150.18 | £ 148.53 | £ 146.90 | £ 145.28 | £ 143.68 | £ 142.10 |
| 21 | SAK-Series | £ 130.88 | £ 129.44 | £ 128.02 | £ 126.61 | £ 125.22 | £ 123.84 | £ 122.48 | £ 121.13 | £ 119.80 |
| 22 | SAK-Series | £ 130.88 | £ 129.44 | £ 128.02 | £ 126.61 | £ 125.22 | £ 123.84 | £ 122.48 | £ 121.13 | £ 119.80 |
| 23 | SAK-Series | £ 139.52 | £ 137.99 | £ 136.47 | £ 134.97 | £ 133.48 | £ 132.01 | £ 130.56 | £ 129.13 | £ 127.70 |
| 24 | SAK-Series | £ 144.00 | £ 142.42 | £ 140.85 | £ 139.30 | £ 137.77 | £ 136.25 | £ 134.75 | £ 133.27 | £ 131.81 |
| 25 | Accessories SAK | £ 37.59 | £ 37.18 | £ 36.77 | £ 36.36 | £ 35.96 | £ 35.57 | £ 35.18 | £ 34.79 | £ 34.41 |
| 26 | Accessories Others | £ 3.16 | £ 3.13 | £ 3.09 | £ 3.06 | £ 3.02 | £ 2.99 | £ 2.96 | £ 2.92 | £ 2.89 |
| 27 | Accessories Others | £ 1.91 | £ 1.89 | £ 1.87 | £ 1.85 | £ 1.83 | £ 1.81 | £ 1.79 | £ 1.77 | £ 1.75 |
| 28 | Accessories SAK | £ 38.21 | £ 37.79 | £ 37.37 | £ 36.96 | £ 36.56 | £ 36.15 | £ 35.76 | £ 35.36 | £ 34.97 |
| 29 | Accessories SAK | £ 34.69 | £ 34.31 | £ 33.93 | £ 33.56 | £ 33.19 | £ 32.82 | £ 32.46 | £ 32.11 | £ 31.75 |
| 30 | Accessories SAK | £ 34.69 | £ 34.31 | £ 33.93 | £ 33.56 | £ 33.19 | £ 32.82 | £ 32.46 | £ 32.11 | £ 31.75 |

Calculation View

☑ Show Formulas Only

| | |
|---|---|
| Depreciation B1 | =99% |
| HoldingCost E1 | =0.1% |
| C3:N1002 | =B3*Depreciation-(B3*HoldingCost) |
| TotalPresentValue Q3 | =SUM(C3:C1002) |
| TotalEndValue Q4 | =SUM(N3:N1002) |
| TotalLoss Q5 | =TotalPresentValue-TotalEndValue |

See and edit your formulae as a list.

File | Home | Insert | Draw | Page Layout | Formulas | Data | Review | View | Developer | Add-ins | LOAD TEST | Team | Tell me what you want to do | Share

Insert Function | AutoSum | Recently Used | Financial | Logical | Text | Date & Time | Lookup & Reference | Math & Trig | More Functions | Name Manager | Define Name | Use in Formula | Create from Selection | Trace Precedents | Trace Dependents | Remove Arrows | Show Formulas | Error Checking | Evaluate Formula | Watch Window | Calculation Options | Calculate Now | Calculate Sheet

Function Library | Defined Names | Formula Auditing | Calculation

C3    =B3*Depreciation-(B3*HoldingCost)

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Depreciation | 99% | | HoldingCost | 0.10% | | | | | |
| 2 | Assets | Present value | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
| 3 | Terminal with Electronic Components | £ 2,728.17 | £ 2,698.16 | £ 2,668.48 | £ 2,639.13 | £ 2,610.10 | £ 2,581.39 | £ 2,552.99 | £ 2,524.91 | £ 2,497.13 | £ 2 |
| 4 | Accessories Others | £ 196.77 | £ 194.61 | £ 192.46 | £ 190.35 | £ 188.25 | £ 186.18 | £ 184.14 | | | |
| 5 | Accessories SAK | £ 10.32 | £ 10.21 | £ 10.09 | £ 9.98 | £ 9.87 | | | | | |
| 6 | Accessories SAK | £ 38.28 | £ 37.86 | £ 37.44 | £ 37.03 | £ 36.62 | | | | | |
| 7 | Other Terminals | £ 388.88 | £ 384.60 | £ 380.37 | £ 376.19 | £ 372.05 | £ 407 | | | | |
| 8 | SAK-Series | £ 430.48 | £ 425.74 | £ 421.06 | £ 416.43 | £ 411.85 | | | | | |
| 9 | SAK-Series | £ 731.01 | £ 722.97 | £ 715.02 | £ 707.15 | £ 699.37 | £ 691.68 | £ 684.07 | | | |
| 10 | SAK-Series | £ 423.61 | £ 418.95 | £ 414.34 | £ 409.78 | £ 405.28 | £ 400.82 | £ 396.41 | £ 392.05 | £ 387.74 | |
| 11 | SAK-Series | £ 397.49 | £ 393.12 | £ 388.79 | £ 384.52 | £ 380.29 | £ 376.10 | £ 371.97 | £ 367.87 | £ 363.8 | £ |
| 12 | SAK-Series | £ 321.88 | £ 318.34 | £ 314.84 | £ 311.37 | £ 307.95 | £ 304.56 | £ 301.21 | £ 297.90 | £ 29 .62 | £ |
| 13 | SAK-Series | £ | 646.16 | 639.05 | £ 632.02 | £ 625.07 | £ 618.19 | £ 611.39 | £ 604.67 | £ |
| 14 | SAK-Series | £ 748.58 | | 724.15 | £ 716.18 | £ 708.30 | £ 700.51 | £ 692.81 | £ 685.19 | £ |
| 15 | Coupler | £ 53.97 | £ 53.38 | | £ 51.63 | £ 51.07 | £ 50.50 | £ 49.5 | £ 49.40 | £ |
| 16 | SAK-Series | £ 352.44 | £ 348.56 | £ 344.72 | £ 337.19 | £ 333.48 | £ 29.81 | £ 326.18 | £ |
| 17 | SAK-Series | £ 354.26 | £ 350.36 | £ 342.69 | £ 338.92 | £ 335.20 | £ 331.51 | £ |
| 18 | Coupler | £ 49.81 | £ 49.26 | £ 47.65 | £ 47.13 | £ 46.61 | £ 46.10 | £ 45.59 | £ |
| 19 | SAK-Series | £ 226.86 | £ 224.36 | £ 217.04 | £ 214.65 | £ 212.29 | £ 209.95 | £ |
| 20 | SAK-Series | £ 151.85 | £ 150.18 | £ 148.53 | £ 145.28 | £ 143.68 | £ 142.10 | £ |
| 21 | SAK-Series | £ 130.88 | £ 126.61 | £ 125.22 | £ 123.84 | £ 122.48 | £ 121.13 | £ 119.80 | £ |
| 22 | SAK-Series | £ 130.88 | £ 129.44 | £ 128.02 | £ 123.84 | £ 122.48 | £ 121.13 | £ 119.80 | £ |
| 23 | SAK-Series | £ 136.47 | £ 134.97 | £ 132.01 | £ 130.56 | £ 129.13 | £ 127.70 | £ |
| 24 | SAK-Series | £ 144.00 | £ 139.30 | £ 137.77 | £ 136.25 | £ 134.75 | £ 133.27 | £ 131.81 | £ |
| 25 | Accessories SAK | £ 37.59 | £ 37.18 | £ 35.96 | £ 35.57 | £ 35.18 | £ 34.79 | £ 34.41 | £ |
| 26 | Accessories Others | £ 3.16 | £ 3.13 | £ 3.09 | £ 3.00 | £ 2.99 | £ 2.96 | £ 2.92 | £ 2.89 | £ |
| 27 | Accessories Others | £ 1.91 | £ 1.89 | £ 1.87 | £ 1.85 | £ 1.83 | £ 1.81 | £ 1.79 | £ 1.77 | £ 1.75 | £ |
| 28 | Accessories SAK | £ 38.21 | £ 37.79 | £ 37.37 | £ 36.96 | £ 36.56 | £ 36.15 | £ 35.76 | £ 35.36 | £ 34.97 | £ |
| 29 | Accessories SAK | £ 34.69 | £ 34.31 | £ 33.93 | £ 33.56 | £ 33.19 | £ 32.82 | £ 32.46 | £ 32.11 | £ 31.75 | £ |
| 30 | Accessories SAK | £ 34.69 | £ 34.31 | £ 33.93 | £ 33.56 | £ 33.19 | £ 32.82 | £ 32.46 | £ 32.11 | £ 31.75 | £ |

**Calculation View**

☑ Show Formulas Only

Depreciation B1 = 99%

HoldingCost E1 = 0.1%

C3:N1002 = B3*Depreciation-(B3*HoldingCost)

...Value Q3 = SUM(C3:C1002) ...(...N1002)

TotalLoss Q5 = TotalPresentValue-TotalEndValue

**Shared formulae (e.g., copy/pasted or drag-filled) are grouped and can be viewed and edited as one.**

It's **easy to name cells** and use names in formulae. This makes formulae more readable.

Formulas Only

Depreciation B1 **=99%**

HoldingCost E1 **=0.1%**

C3:N1002 **=B3*Depreciation-(B3*HoldingCost)**

TotalPresentValue Q3 **=SUM(C3:C1002)**

TotalEndValue Q4 **=SUM(N3:N1002)**

TotalLoss Q5 **=TotalPresentValue-TotalEndValue**

**Sorting**

calculation-view

Sort | Filter | Search | Refresh

Sort Descending

Sort by:

Row wise
Column wise
Formula length
Alphabetical

="Normal","Calc View","Normal")

ormal])*100

T206:U206=MEDIAN(T184:T205)
AB206:AC206=MEDIAN(AB184:AB205)
K222=MEDIAN([Difference])
L222=MEDIAN([Difference %])
C229:D316=LOG10(F229)
T248:U248=MEDIAN(T226:T247)
AB248:AC248=MEDIAN(AB226:AB247)

| | A | B | C | D | E | F | G | H | I | J | K | L | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Participa | First condition | Task 1 c | Task 1 t | Task 2 | Task 2 | Task 3 | Task 3 | Task 4 | Task 4 | Secon | Task 5 c | Tas |
| 2 | 1 | Normal | W1A | 158 | W2A | 283 | D1A | 63 | D2A | 77 | Calc View | W1B | 104 |
| 3 | 2 | Normal | W1B | 170 | W2B | 182 | D1B | 246 | D2B | 122 | Calc View | W1A | 60 |
| 4 | 3 | Calc View | W2A | 258 | W1A | 80 | D2A | 213 | D1A | 78 | Normal | W2B | 235 |
| 5 | 4 | Calc View | W2B | 313 | W1B | 31 | D2B | 125 | D1B | 100 | Normal | W2A | 185 |
| 6 | 5 | Normal | W1A | 172 | W2A | 129 | D1A | 262 | | | | W1B | 61 |
| 7 | 6 | Normal | W1B | 512 | W2B | 215 | D1B | 223 | | | Normal | W1A | 45 |
| 8 | 7 | Calc View | W2A | 400 | W1A | 68 | D2A | 160 | | 124 | Normal | W1A | 307 |
| 9 | 8 | Calc View | W2B | 144 | W1B | 64 | D2B | 58 | D1B | 52 | Normal | W2A | 102 |
| 10 | 9 | Normal | W1A | 164 | W2A | 110 | D1A | 70 | D2A | 110 | Calc View | W1B | 59 |
| 11 | 10 | Normal | W1B | 193 | W2B | 287 | D1B | 75 | D2B | 59 | Calc View | W1A | 120 |
| 12 | 11 | Calc View | W2A | 240 | W1A | 120 | D2A | 83 | D1A | 23 | Normal | W2B | 266 |
| 13 | 12 | Calc View | W2B | 178 | W1B | 38 | D2B | 27 | D1B | 14 | Normal | W2A | 163 |
| 14 | 13 | Normal | W1A | 450 | W2A | 337 | D1A | 394 | D2A | 83 | Calc View | W1B | 103 |
| 15 | 14 | Normal | W1B | 73 | W2B | 134 | D1B | 120 | D2B | 55 | Calc View | W1A | 68 |
| 16 | 15 | Calc View | W2A | 110 | W1A | 50 | D2A | 50 | D1A | 44 | Normal | W2B | 175 |
| 17 | 16 | Calc View | W2B | 88 | W1B | 44 | D2B | 24 | D1B | 53 | Normal | W2A | 202 |
| 18 | 17 | Normal | W1A | 69 | W2A | 60 | D1A | 54 | D2A | 32 | Calc View | W1B | 27 |
| 19 | 18 | Normal | W1B | 341 | W2B | 388 | D1B | 72 | D2B | 22 | Calc View | W1A | 62 |
| 20 | 19 | Calc View | W2A | 80 | W1A | 72 | D2A | 27 | D1A | 26 | Normal | W2B | 428 |
| 21 | 20 | Calc View | W2B | 64 | W1B | 48 | D2B | 22 | D1B | 44 | Normal | W2A | 181 |
| 22 | 21 | Normal | W1A | 157 | W2A | 222 | D1A | 68 | D2A | 38 | Calc View | W1B | 52 |
| 23 | 22 | Normal | W1B | 375 | W2B | 408 | D1B | 63 | D2B | 33 | Calc View | W1A | 60 |
| 24 | 23 | Calc View | W2A | | W1A | | D2A | | D1A | | Normal | W2B | |
| 25 | 24 | Calc View | W2B | | W1B | | D2B | | D1B | | Normal | W2A | |

| | Minutes | Second | | | | Particip | Task co | Task ty | Normal | CV | Differe | Differen |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 3 | 180 | | | | 1 | D1 | D | 63 | 161 | -98 | -155.56 |
| 34 | 4 | 240 | | | | 1 | D2 | D | 77 | 180 | -103 | -133.77 |
| 37 | 7 | 420 | | | | 2 | D1 | D | 246 | 90 | 156 | 63.41 |
| 38 | 8 | 480 | | | | 2 | D2 | D | 122 | 67 | 55 | 45.08 |
| 41 | | | | | | 3 | D2 | D | 54 | 219 | -165 | -305.56 |
| 42 | | | | | | 3 | D1 | D | 65 | 78 | -13 | -20.00 |
| 45 | | | | | | 4 | D2 | D | 300 | 125 | 175 | 58.33 |
| 46 | | | | | | 4 | D1 | D | 143 | 100 | 43 | 30.07 |
| 49 | | | | | | 5 | D1 | D | 262 | 83 | 179 | 68.32 |
| 50 | | | | | | 5 | D2 | D | 182 | 59 | 123 | 67.58 |
| 53 | | | | | | 6 | D1 | D | 223 | 48 | 175 | 78.48 |
| 54 | | | | | | 6 | D2 | D | 40 | 20 | 20 | 50.00 |
| 57 | | | | | | 7 | D2 | D | 136 | 160 | -24 | -17.65 |
| 58 | | | | | | 7 | D1 | D | 178 | 124 | 54 | 30.34 |
| 61 | | | | | | 8 | D2 | D | 24 | 58 | -34 | -141.67 |

# Sort by formula length

**Experiment data v2 (final).xlsx** - Last Saved 11/10/2018 15:39 — Advait Sarkar

Cell: T260

| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Participa | First condition | Task 1 c | Task 1 t | Task 2 | Task 2 | Task 3 | Task 3 | Task 4 | Task 4 | Secon | Task 5 c |
| 2 | 1 | Normal | W1A | 158 | W2A | 283 | D1A | | D2A | 77 | Calc View | W1B 104 |
| 3 | 2 | Normal | W1B | 170 | W2B | 182 | D1B | | D2B | | Calc View | W1A 60 |
| 4 | 3 | Calc View | W2A | 258 | W1A | 80 | D2A | 78 | | | Normal | W2B 235 |
| 5 | 4 | Calc View | W2B | 313 | W1B | 31 | | | | | Normal | W2A 185 |
| 6 | 5 | Normal | W1A | 172 | W2A | 110 | D1A | 262 | D2A | 182 | Calc View | W1B 61 |
| 7 | 6 | Normal | W1B | 512 | W2B | | D1B | 223 | D2B | 40 | Calc View | W1A 45 |
| 8 | 7 | Calc View | W2A | 400 | | | D1A | | | | Normal | W2A 307 |
| 9 | 8 | Calc View | W2B | 144 | W1B | | | | D1A | | Normal | W2A 102 |
| 10 | 9 | Normal | W1A | 164 | W2A | 110 | | | | | | W1B 59 |
| 11 | 10 | Normal | W1B | 193 | W2B | 287 | D1B | 75 | D2B | | Normal | 120 |
| 12 | 11 | Calc View | W2A | 240 | W1A | 120 | D1A | 23 | | | Normal | W2A 266 |
| 13 | 12 | Calc View | W2B | 178 | W1B | 38 | D2B | 27 | D1B | 14 | Normal | 163 |
| 14 | 13 | Normal | W1A | 450 | W2A | 337 | D1A | 394 | D2A | 83 | Calc View | W1B 103 |
| 15 | 14 | Normal | W1B | 73 | W2B | 134 | D1B | 120 | D2B | 55 | Calc View | W1A 68 |
| 16 | 15 | Calc View | W2A | 110 | W1A | 50 | D2A | 50 | D1A | 44 | Normal | W2B 175 |
| 17 | 16 | Calc View | W2B | 88 | W1B | 44 | D2B | 24 | D1B | 53 | Normal | W2A 202 |
| 18 | 17 | Normal | W1A | 69 | W2A | 60 | D1A | 54 | D2A | 32 | Calc View | W1B 27 |
| 19 | 18 | Normal | W1B | 341 | W2B | 388 | D1B | 72 | D2B | 22 | Calc View | W1A 62 |
| 20 | 19 | Calc View | W2A | 80 | W1A | 72 | D2A | 27 | D1A | 26 | Normal | W2B 428 |
| 21 | 20 | Calc View | W2B | 64 | W1B | 48 | D2B | 22 | D1B | 44 | Normal | W2A 181 |
| 22 | 21 | Normal | W1A | 157 | W2A | 222 | D1A | 68 | D2A | 38 | Calc View | W1B 52 |
| 23 | 22 | Normal | W1B | 375 | W2B | 408 | D1B | 63 | D2B | 33 | Calc View | W1A 60 |
| 24 | 23 | Calc View | W2A | | W1A | | D2A | | D1A | | Normal | W2B |
| 25 | 24 | Calc View | W2B | | W1B | | D2B | | D1B | | Normal | W2A |

| | Minutes | Second | | | Particip | Task co | Task ty | Normal | CV | Differe | Differen |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 3 | 180 | | | 1 | D1 | D | 63 | 161 | -98 | -155.56 |
| 34 | 4 | 240 | | | 1 | D2 | D | 77 | 180 | -103 | -133.77 |
| 37 | 7 | 420 | | | 2 | D1 | D | 246 | 90 | 156 | 63.41 |
| 38 | 8 | 480 | | | 2 | D2 | D | 122 | 67 | 55 | 45.08 |
| 41 | | | | | 3 | D2 | D | 54 | 219 | -165 | -305.56 |
| 42 | | | | | 3 | D1 | D | 65 | 78 | -13 | -20.00 |
| 45 | | | | | 4 | D2 | D | 300 | 125 | 175 | 58.33 |
| 46 | | | | | 4 | D1 | D | 143 | 100 | 43 | 30.07 |
| 49 | | | | | 5 | D1 | D | 262 | 83 | 179 | 68.32 |
| 50 | | | | | 5 | D2 | D | 182 | 59 | 123 | 67.58 |
| 53 | | | | | 6 | D1 | D | 223 | 48 | 175 | 78.48 |
| 54 | | | | | 6 | D2 | D | 40 | 20 | 20 | 50.00 |
| 57 | | | | | 7 | D2 | D | 136 | 160 | -24 | -17.65 |
| 58 | | | | | 7 | D1 | D | 178 | 124 | 54 | 30.34 |
| 61 | | | | | 8 | D2 | D | 24 | 58 | -34 | -141.67 |

## calculation-view

Sort ▾ | Filter ▾ | Search | Refresh

- K2:K25=IF([@[First condition]]="Normal","Calc View","Normal")
- L31:L118=([@Difference]/[@Normal])*100
- L222=MEDIAN([Difference %])
- L171=MEDIAN([Difference %])
- L119=MEDIAN([Difference %])
- K222=MEDIAN([Difference])
- K171=MEDIAN([Difference])
- K119=MEDIAN([Difference])
- AB248:AC248=MEDIAN(AB226:AB247)
- AB206:AC206=MEDIAN(AB184:AB205)
- T248:U248=MEDIAN(T226:T247)
- T206:U206=MEDIAN(T184:T205)
- K31:K118=[@Normal]-[@CV]
- C31:C40=[@Minutes]*60
- C229:D316=LOG10(F229)
- H31:H118=LEFT(G31,1)

# Filtering

| | A | B | C | D | E | F | G | H | I | J | K | L | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Participa | First condition | Task 1 c | Task 1 t | Task 2 | Task 2 | Task 3 | Task 3 | Task 4 | Task 4 | Secon | Task 5 c | Tas |
| 2 | 1 | Normal | W1A | 158 | W2A | 283 | D1A | 63 | D2A | 77 | Calc View | W1B | 104 |
| 3 | 2 | Normal | W1B | 170 | W2B | 182 | D1B | 246 | D2B | 122 | Calc View | W1A | 60 |
| 4 | 3 | Calc View | W2A | 258 | W1A | 80 | D2A | 219 | D1A | 78 | Normal | W2B | 235 |
| 5 | 4 | Calc View | W2B | 313 | W1B | 31 | D2B | 100 | D1B | 100 | Normal | W2A | 185 |
| 6 | 5 | Normal | W1A | 172 | W2A | 129 | D1A | | D2A | | Calc View | W1B | 61 |
| 7 | 6 | Normal | W1B | 512 | W2B | 215 | D1B | | D2B | | Normal | W1A | 45 |
| 8 | 7 | Calc View | W2A | 400 | W1A | 68 | D2A | 160 | D1A | | W2B | 307 |
| 9 | 8 | Calc View | W2B | 144 | W1B | 64 | D2B | 58 | D1B | 52 | Normal | W2A | 102 |
| 10 | 9 | Normal | W1A | 164 | W2A | 110 | D1A | 70 | D2A | | W1B | 59 |
| 11 | 10 | Normal | W1B | 193 | W2B | 287 | D1B | 75 | D2B | 59 | Calc View | W1A | 120 |
| 12 | 11 | Calc View | W2A | 240 | W1A | 120 | D2A | 83 | D1A | 23 | Normal | W2B | 266 |
| 13 | 12 | Calc View | W2B | 178 | W1B | 38 | D2B | 27 | D1B | 14 | Normal | W2A | 163 |
| 14 | 13 | Normal | W1A | 450 | W2A | 337 | D1A | 394 | D2A | 83 | Calc View | W1B | 103 |
| 15 | 14 | Normal | W1B | 73 | W2B | 134 | D1B | 120 | D2B | 55 | Calc View | W1A | 68 |
| 16 | 15 | Calc View | W2A | 110 | W1A | 50 | D2A | 50 | D1A | 44 | Normal | W2B | 175 |
| 17 | 16 | Calc View | W2B | 88 | W1B | 44 | D2B | 24 | D1B | 53 | Normal | W2A | 202 |
| 18 | 17 | Normal | W1A | 69 | W2A | 60 | D1A | 54 | D2A | 32 | Calc View | W1B | 27 |
| 19 | 18 | Normal | W1B | 341 | W2B | 388 | D1B | 72 | D2B | 22 | Calc View | W1A | 62 |
| 20 | 19 | Calc View | W2A | 80 | W1A | 72 | D2A | 27 | D1A | 26 | Normal | W2B | 428 |
| 21 | 20 | Calc View | W2B | 64 | W1B | 48 | D2B | 22 | D1B | 44 | Normal | W2A | 181 |
| 22 | 21 | Normal | W1A | 157 | W2A | 222 | D1A | 68 | D2A | 38 | Calc View | W1B | 52 |
| 23 | 22 | Normal | W1B | 375 | W2B | 408 | D1B | 63 | D2B | 33 | Calc View | W1A | 60 |
| 24 | 23 | Calc View | W2A | | W1A | | D2A | | D1A | | Normal | W2B | |
| 25 | 24 | Calc View | W2B | | W1B | | D2B | | D1B | | Normal | W2A | |

| | Minutes | Second | | | Particip | Task co | Task ty | Normal | CV | Differe | Differen |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | 3 | 180 | | | 1 | D1 | D | 63 | 161 | -98 | -155.56 |
| 34 | 4 | 240 | | | 1 | D2 | D | 77 | 180 | -103 | -133.77 |
| 37 | 7 | 420 | | | 2 | D1 | D | 246 | 90 | 156 | 63.41 |
| 38 | 8 | 480 | | | 2 | D2 | D | 122 | 67 | 55 | 45.08 |
| 41 | | | | | 3 | D2 | D | 54 | 219 | -165 | -305.56 |
| 42 | | | | | 3 | D1 | D | 65 | 78 | -13 | -20.00 |
| 45 | | | | | 4 | D2 | D | 300 | 125 | 175 | 58.33 |
| 46 | | | | | 4 | D1 | D | 143 | 100 | 43 | 30.07 |
| 49 | | | | | 5 | D1 | D | 262 | 83 | 179 | 68.32 |
| 50 | | | | | 5 | D2 | D | 182 | 59 | 123 | 67.58 |
| 53 | | | | | 6 | D1 | D | 223 | 48 | 175 | 78.48 |
| 54 | | | | | 6 | D2 | D | 40 | 20 | 20 | 50.00 |
| 57 | | | | | 7 | D2 | D | 136 | 160 | -24 | -17.65 |
| 58 | | | | | 7 | D1 | D | 178 | 124 | 54 | 30.34 |
| 61 | | | | | 8 | D2 | D | 24 | 58 | -34 | -141.67 |

## calculation-view

Sort  Filter  Search  Refresh

- ✓ Formulas only
- Values only
- Named items only
- Precedents and Dependents ►
- 🔽 Clear Filters

K2:K25=IF([@[F...al")
L31:L118=([@D...
L222=MEDIAN(
L171=MEDIAN(
L119=MEDIAN(
K222=MEDIAN(
K171=MEDIAN(
K119=MEDIAN((Difference))
AB248:AC248=MEDIAN(AB226:AB247)
AB206:AC206=MEDIAN(AB184:AB205)
T248:U248=MEDIAN(T226:T247)
T206:U206=MEDIAN(T184:T205)
K31:K118=[@Normal]-[@CV]
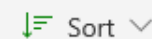C31:C40=[@Minutes]*60
C229:D316=LOG10(F229)
H31:H118=LEFT(G31,1)

File | Home | Insert | Draw | Page Layout | Formulas | Data | Review | View | Add-ins | Help | Team | Design | Tell me what you want to do | Share

E36 | $f_x$ =R9-E9

**Precedents and dependents**

Normal

| Partici▾ | Q1 ▾ | Q2 ▾ | Q3 ▾ | Q4 ▾ | Q5 ▾ | Q6 ▾ | Q7 ▾ | Q8 ▾ | Q9 ▾ | Q10 ▾ | Aver. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 0 | 3 | 4 | 7 | | | | | | |
| 2 | 6 | 0 | 6 | 4 | 8 | | | | | | |
| 3 | 9 | 7 | 7 | 7 | 8 | | | | | 7.5 | |
| 4 | 7 | 4 | 5 | 8 | 8 | | | | | 7.3 | |
| 5 | 3 | 3 | 4 | 7 | 8 | | | | | 5.5 | |
| 6 | 5 | 6 | 5 | 8 | 7 | 7 | 7 | 6 | 6 | | |
| 7 | 8 | 5 | 7 | 7 | 8 | 8.5 | 8.5 | | | | |
| 8 | 8 | 5 | 6 | 8 | 10 | 7 | | | | 7.2 | |
| 9 | 7 | 0 | 5 | 5 | | | | | | 6.4 | |
| 10 | 9 | 2 | 6 | 7 | 9 | | 10 | | | 7.2 | |
| 11 | 8 | 4 | 8 | 8 | | | | | | 8.3 | |
| 12 | 9 | 6 | 10 | 9 | 10 | | | 10 | 10 | 9.2 | |
| 13 | 1 | 0 | 2 | 1 | 2 | 1 | 0 | 1 | 2 | 1.3 | |
| 14 | 9 | 3 | 8 | 10 | 9 | 9 | 10 | 9 | | 8.6 | |
| 15 | 5 | 4 | 7 | 8 | 8 | 8 | 8 | 6 | 7 | 6.9 | |
| 16 | 7 | 7 | 4 | 8 | 10 | 9 | 9 | 7 | 10 | 7.9 | |
| 17 | 10 | 6 | 8 | 5 | 10 | 10 | 10 | 7 | 10 | 8.6 | |
| 18 | 2 | 3 | 6 | 10 | 10 | 9 | 8 | 7 | 9 | 7.3 | |
| 19 | 7 | 0 | 7 | 8 | 0 | 8 | 7 | 5 | 8 | 5.8 | |
| 20 | 5 | 2 | 8 | 8 | 10 | 8 | 8 | 8 | 10 | 7.7 | |
| 21 | 7 | 3 | 7 | 7 | 8 | 8 | 8 | 8 | 8 | 7.2 | |
| 22 | 3 | 1 | 3 | 5 | 10 | 10 | 4 | 10 | 8 | 6.2 | |

**Difference (CV - Normal), higher is better**

| Partici▾ | Q1 ▾ | Q2 ▾ | Q3 ▾ | Q4 ▾ | Q5 ▾ | Q6 ▾ | Q7 ▾ | Q8 ▾ | Q9 ▾ | Q10 ▾ | Aver. ▾ | | Question |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 3 | 3 | 1 | -2 | 0 | 0 | 1 | 3 | 2 | 1.4 | | 1 ... if there was no one around |
| 2 | -2 | 0 | 0 | 2 | 0 | 1 | 1 | 2 | -2 | 1 | 0.3 | | 2 ... if I had never used a pack |
| 3 | -2 | -5 | -2 | -1 | -4 | -2 | -5 | 0 | 0 | 0 | -2.1 | | 3 ... if I only had the manual for |
| 4 | -3 | -2 | 1 | -1 | 2 | 1 | -5 | 0 | 1 | 0 | -0.6 | | 4 ... if I had seen someone else |
| 5 | 7 | 7 | 6 | 3 | 2 | 2 | 7 | 7 | 2 | 2 | 4.5 | | 5 ... if I could call someone for |
| 6 | 5 | -1 | 2 | -1 | 0 | 0 | 1 | 1 | 0 | 2 | 0.9 | | 6 ... if someone else had helpe |
| 7 | 1 | -2 | -2 | 1 | 1 | 0.5 | 0.5 | 1 | 0.5 | 1 | 0.25 | | 7 ... if I had a lot of time to comp |
| 8 | 0 | 0 | 0 | -1 | 0 | 1 | 1 | 1 | 1 | 1 | 0.3 | | 8 ... if I had only the built-in hel |
| 9 | 1 | 0 | 3 | 3 | 0 | 1 | 0 | 1 | 0 | 1 | 0.8 | | 9 ... if someone showed me ho |
| 10 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | -1 | 0.3 | | 10 ... if I had used similar packa |
| 11 | -2 | -1 | 0 | 1 | 0 | 0 | 0 | 0 | -1 | -7 | -1 | | |
| 12 | -2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -0.3 | | |
| 13 | 3 | 0 | 1 | 2 | 0 | 2 | 2 | 2 | 3 | 0 | 1.5 | | |
| 14 | -3 | -1 | 0 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | -0.5 | | |
| 15 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | -0.2 | | 1 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |

**calculation-view**

Sort | Filter | Search | Refresh

Precedents (current sheet only):

Y3:Y24=AVERAGE(Table5[@[Q1]:[Q10]])

L3:L24=AVERAGE(Table57[@[Q1]:[Q10]])

Grid selection:

B30:L51=**O3-B3**

Dependents (current sheet only):

O44=E36

# Grid-aware search

Excel — Experiment data v2 (final).xlsx - Saved to OneDrive - Microsoft — Advait Sarkar

Cell: H62 = -7.66666666666667

## Normal

| Participant | Mental demand | Physical demand | Temporal Demand | Performance | Effort | Frustration | Average |
|---|---|---|---|---|---|---|---|
| 1 | 18 | 2 | | | | | 17 |
| 2 | 19 | 10 | 11 | 13 | 16 | 16 | 14.17 |
| 3 | 3 | 16 | 7 | 3 | 4 | 7 | 6.67 |
| 4 | 15 | 7 | 16 | 16 | 7 | | 12.83 |
| 5 | 12 | 10 | 18 | 18 | 7 | | 15.67 |
| 6 | 5 | 2 | 2 | 12 | 7 | 14 | 7.00 |
| 7 | 11 | 2 | 11 | 4 | 11 | 7 | 7.67 |
| 8 | 11 | 6 | 6 | 2 | 11 | 2 | 6.33 |
| 9 | 15 | 11 | 18 | 4 | 15 | 5 | 11.33 |
| 10 | 4 | 3 | 15 | 4 | 4 | 3 | 5.50 |
| 11 | 12 | 1 | 4 | 4 | 11 | 6 | 6.33 |
| 12 | 15 | 2 | 1 | 4 | 10 | 2 | 5.67 |
| 13 | 15 | 3 | 11 | 8 | 15 | 14 | 11.00 |
| 14 | 7 | 1 | 3 | 3 | 8 | 2 | 4.00 |
| 15 | 4 | 2 | 5 | 5 | 5 | 2 | 3.83 |
| 16 | 14 | 10 | 3 | 6 | 11 | 9 | 8.83 |
| 17 | 3 | 1 | 5 | 1 | 2 | 6 | 3.00 |
| 18 | 13 | 4 | 4 | 13 | 16 | 12 | 10.33 |
| 19 | 2 | 2 | 2 | 8 | 6 | 6 | 4.33 |
| 20 | 17 | 1 | 11 | 6 | 16 | 6 | 9.50 |
| 21 | 13 | 11 | 13 | 5 | 12 | 6 | 10.00 |
| 22 | 14 | 1 | 1 | 17 | 11 | 11 | 9.17 |

## Difference (CV - normal), lower is better

| Participant | Mental demand | Physical demand | Temporal Demand | Performance | Effort | Frustration | Average |
|---|---|---|---|---|---|---|---|
| 1 | -14 | 0 | -8 | -3 | -2 | -2 | -4.83 |
| 2 | -9 | 1 | -3 | -6 | -7 | -6 | -5.00 |
| 3 | 3 | -1 | -2 | 2 | 4 | -3 | 0.50 |
| 6 | -3 | 0 | 0 | -8 | -5 | -12 | -4.67 |
| 10 | 3 | 0 | -11 | 5 | -1 | 0 | -0.67 |
| 13 | -8 | -1 | -2 | 0 | -4 | -6 | -3.50 |
| 18 | -4 | -2 | -1 | -2 | -6 | -6 | -3.50 |

### calculation-view

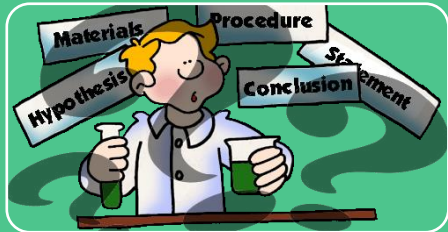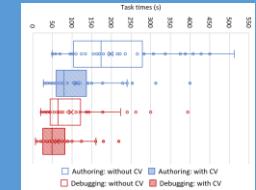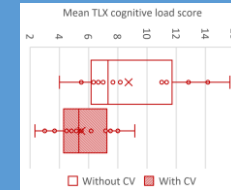Sort | Filter | H15 | Refresh

Search Results for: H15

H3:H24=AVERAGE(Table4[@[Mental demand]:[Frustration]])

# Studying calculation view

## Authoring & debugging

- 20 participants, variety of backgrounds & expertise
- Improvement in task time and cognitive load

## Comprehension

- 14 participants, spreadsheet comprehension test
- Improvement in comprehension and cognitive load in half the participants

## Longitudinal deployment

- 7 MVPs, using CV for day to day work, ongoing reporting back
- Many uses, most positive feedback around auditing and comprehension

# MVP feedback

- ## Solves the problem that formula view is aimed at
  - P6: *"[The current show formulas feature] is useless to me. [...] One of the most particular things that accountants do is get column size exactly right. And I need to see what the numbers are. I'm going to say words I've never said before. I like the fact that [Calc View] is in a task pane. That makes me feel dirty inside. But I love that I don't have to manipulate the sheet to flip it into formula view. Don't have to flip the grid. You guys are absolutely on the right track."*

- ## Very helpful for auditing and debugging
  - P17: *"Calc View has already been extremely useful to me in identifying spurious formulae, no longer needed, and the situation where not all formulae in a row had been amended to the newer [...] version. Calc View is already a winner!!"*
  - P9: *"Just plain text search is really good."*
  - P6: *"Cool to have name, location and formula in one place. Formula evaluation tool is kind of weak. Calc View is a logical place to enable stepping from one thing to another. Maybe don't want to make calc view as rich as formula bar. Maybe just need a quick way to get to the formula bar."*
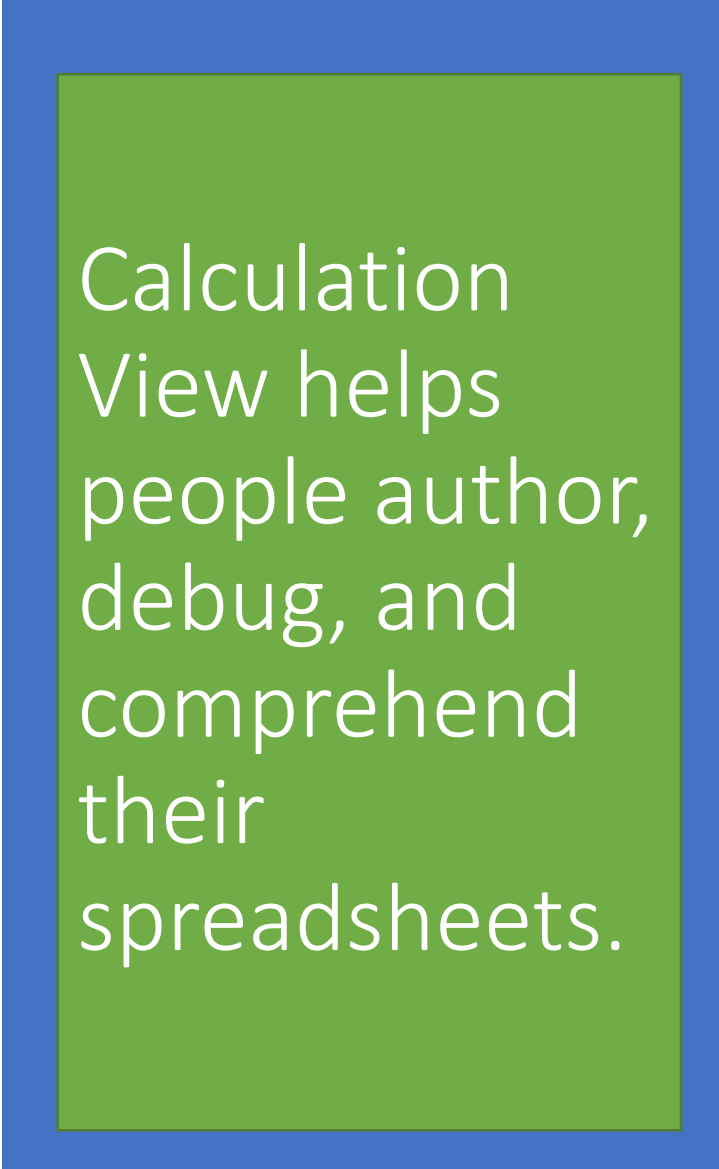
# Calculation View: multiple-representation editing in spreadsheets

Advait Sarkar*, Andrew D. Gordon*†, Simon Peyton Jones*, Neil Toronto*
*Microsoft Research, 21 Station Road, Cambridge, United Kingdom
†University of Edinburgh School of Informatics, 10 Crichton Street, Edinburgh, United Kingdom
{advait,adg,simonpj,netoront}@microsoft.com

- Results from over a year of testing, across three studies, with ~40 total participants from a diverse range of backgrounds.
- A powerful successor to 'show formulas'.

Calculation View helps people author, debug, and comprehend their spreadsheets.

# Elastic Sheet-Defined Functions

Generalising Spreadsheet Functions to Variable-Size Input Arrays

Microsoft Research

Office

# Sheet defined functions

Peyton Jones, S.L., Blackwell, A.F., Burnett, M.M.:
A user-centred approach to functions in Excel. ICFP 165–176 (2003)

1: define function

2: use like any other

|   | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Average function** | | | | | |
| 2 | | | | | | |
| 3 | **Input:** | 4 | | **Count:** | 5 | =COUNT(B3:B7) |
| 4 | | 5 | | **Sum:** | 42 | =SUM(B3:B7) |
| 5 | | 23 | | **Average:** | 8.4 | =E4/E3 |
| 6 | | 4 | | | | |
| 7 | | 6 | | | | |

8.4

# Elastic SDFs

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Average function** | | | | | |
| 2 | | | | | | |
| 3 | **Input:** | 4 | | **Count:** | 5 | =COUNT(B3:B7) |
| 4 | | 5 | | **Sum:** | 42 | =SUM(B3:B7) |
| 5 | | 23 | | **Average:** | 8.4 | =E4/E3 |
| 6 | | 4 | | | | |
| 7 | | 6 | | | | |

In CalcView:

```
function AVERAGE( B3:B7 ) returns E5 {
    E3 = COUNT( B3:B7 )
    E4 = SUM( B3:B7 )
    E5 = E4/E3
}
```

# Elastic SDFs

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Average function** | | | | | |
| 2 | | | | | | |
| 3 | **Input:** | 4 | | **Count:** | 5 | =COUNT(B3:B7) |
| 4 | | 5 | | **Sum:** | 42 | =SUM(B3:B7) |
| 5 | | 23 | | **Average:** | 8.4 | =E4/E3 |
| 6 | | 4 | | | | |
| 7 | | 6 | | | | |

In CalcView:

**function** AVERAGE( B3:B7 ) **returns** E5 {
    E3 = COUNT( B3:B7 )
    E4 = SUM( B3:B7 )
    E5 = E4/E3
}

## Problem:

- =AVERAGE( X5:X7)   too small!
- =AVERAGE( G2:G200 )   too big!

# Elastic SDFs

## Solution:

- Somehow generalize what the user wrote



| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Average function** | | | | | |
| 2 | | | | | | |
| 3 | Input: | 4 | | Count: | 5 | =COUNT(B3:B7) |
| 4 | | 5 | | Sum: | 42 | =SUM(B3:B7) |
| 5 | | 23 | | Average: | 8.4 | =E4/E3 |
| 6 | | 4 | | | | |
| 7 | | 6 | | | | |

```
function AVERAGE( B3:B7 ) returns
E5 {

    E3 = COUNT( B3:B7 )

    E4 = SUM( B3:B7 )

    E5 = E4/E3

}
```

```
function AVERAGE<α>( B3:B{3+α} ) returns
E5 {

    E3 = COUNT( B3:B{3+α} )

    E4 = SUM( B3:B{3+α} )

    E5 = E4/E3

}
```

# Elastic SDFs

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | **Average function** | | | | | |
| 2 | | | | | | |
| 3 | **Input:** | 4 | | **Count:** | 5 | =COUNT(B3:B7) |
| 4 | | 5 | | **Sum:** | 42 | =SUM(B3:B7) |
| 5 | | 23 | | **Average:** | 8.4 | =E4/E3 |
| 6 | | 4 | | | | |
| 7 | | 6 | | | | |

**function** AVERAGE**<α>** ( B3:B{3+α} ) **returns** E5 {

    E3 = COUNT( B3:B{3+α} )

    E4 = SUM( B3:B{3+α} )

    E5 = E4/E3

}

Elastic SDF can be called with any $\alpha \geq 0$

=AVERAGE(G2:G200 )

- Figure out $\alpha$ = 198 from the arguments

- Instantiate the SDF sheet with $\alpha$ = 198

- Calc it

- Return the result

- Discard the instantiated sheet

# TIMESHEET

| First na | Last na | Catego | Rate | Date | 01/04/2017 | 02/04/2017 | 03/04/2017 | 04/04/2017 | 05/04/2017 | ###### | ####### | Total hours | Payment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| John | Wire | Full-Time | 20 | | 0 | 0 | 4 | 8 | 0 | 4 | 0 | 16 | 320 |
| Sophie | Gallaghe | Contract | 25 | | 0 | 0 | 0 | 0 | 8 | 8 | 4 | 20 | 500 |
| | | | | | | | | | | | | Total to be pai | 820 |

| First na | Last na | Catego | Rate | Date | 01/08/2017 | 02/08/2017 | 03/08/2017 | 04/08/2017 | 05/08/2017 | ###### | ####### | 08/08/2017 | ####### | ######## | 11/08/2017 | ######## | ######## | 14/08/2017 | Total hours | Payment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| David | Green | Full-Time | 20 | | 0 | 0 | 3 | 0 | 0 | 5 | 0 | 9 | 4 | 0 | 0 | 5 | 0 | 0 | | |
| Sarah | Jones | Full-Time | 20 | | 5 | 7 | 8 | 9 | 0 | 5 | 5 | 10 | 0 | 0 | 4 | 4 | 4 | 4 | | |
| Edward | Muller | Contract | 25 | | 0 | 0 | 0 | 0 | 0 | 8 | 10 | 0 | 5 | 0 | 0 | 8 | 0 | 0 | | |
| Hannah | Kirk | Part-Tim | 15 | | 8 | 0 | 0 | 4 | 0 | 8 | 4 | 0 | 3 | 5 | 3 | 0 | 8 | 8 | | |
| Jo | Carter | Contract | 25 | | 8 | 8 | 8 | 8 | 8 | 0 | 0 | 8 | 8 | 8 | 9 | 0 | 8 | 0 | | |
| Max | Wells | Full-Time | 20 | | 8 | 0 | 0 | 0 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 8 | 8 | 8 | | |
| | | | | | | | | | | | | | | | | | Total to be p | 3:S18)) | |

$$=\mathcal{E}(PAYMENT(D13:D18,F13:S18))$$

# User's eye view

· Write a function with fixed-size inputs, using familiar copy/paste
· Magic happens
· The function works on input of arbitrary size

**Main point:**   we think that automatically inferred elasticity will dramatically broaden the audience that can use SDFs effectively.

# The magic

- It really is quite amazing to
  - Take a single, concrete function working on fixed size inputs
  - And generalise it to arbitrary size inputs
  - In a predictable way

- But we can do it.

- We can even prove that the generalisation we find is the **"best generalisation"** in a very precise sense.  Not just a set of heuristics.

# Findings from user study (N=20, 7 female)

People perceived **significantly lower cognitive workload** for elastic SDFs than with SDFs based on map/reduce.

*I think elastic functions are easier to work with, also with the "mental model" that you have of Excel, because you can more just follow your normal Excel **workflow**. – P9*

*It'd be nice to have this kind of **middle ground**, of not having to write the same things over and over again, but not having to persuade someone to make a macro either. – P7*

# Elastic Sheet-Defined Functions

Automatic generalization of map/reduce programs from example

Theorem: Elasticization yields most general generalization

User study: Easier for end-users than map/reduce programs

**Elastic Sheet-Defined Functions: Generalising Spreadsheet Functions to Variable-Size Input Arrays***

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# Aim

Remove the "glass ceiling" that limits the scope and reach of what a domain expert can do with Excel:

· **Make Excel functions reflect the abstractions of our end users**, by allowing end-users to define new functions using an ordinary worksheet.

· **Make Excel's data values reflect the datatypes of our end users' domains**, by adding arrays, vectors, records, and even domain-specific data types implemented by third parties.

# Yellow Related Links

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Dynamic Arrays and New Functions in Excel! - Office Insider Blog

Video tour of Microsoft Research Cambridge

( gif2xlsx: Convert GIFs to XLSX format )

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