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Studies of Part-to-Whole Glanceable Visualizations on Smartwatch Faces

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Smartwatches

Watch face

Watch Face

- Time
- Complications

Complications: Represent Non-time/date Data

Complications: Represent Non-time/date Data

Representations

- Short texts
- Icons
- Simple visualizations
- Combinations

Usage Contexts: “On the Go” Quick Glances

Monitoring Progress towards Self-set Goals

E.g., How much of my step count goal have I achieved today?

People always have multiple goals

Proportion: Current Value / Goal

- Percentage 70%
- Visualization 

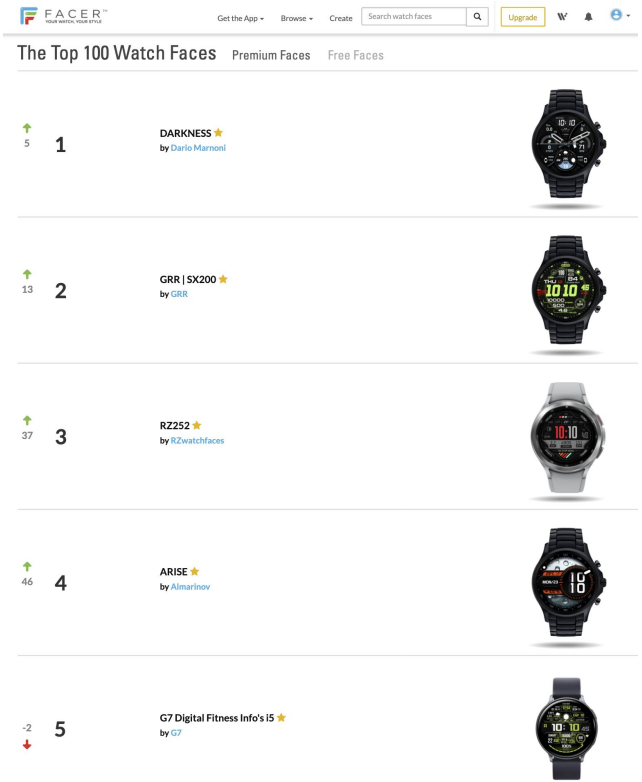
Can people check progress towards different goals at a glance when there are **multiple proportions** on a watch face?

Reading Multiple Proportions at Once

Can this be done at a glance?

- How does the **representation type** matter?
- How does the **complexity of the watch face** matter?
- How does the **viewing angle** matter?

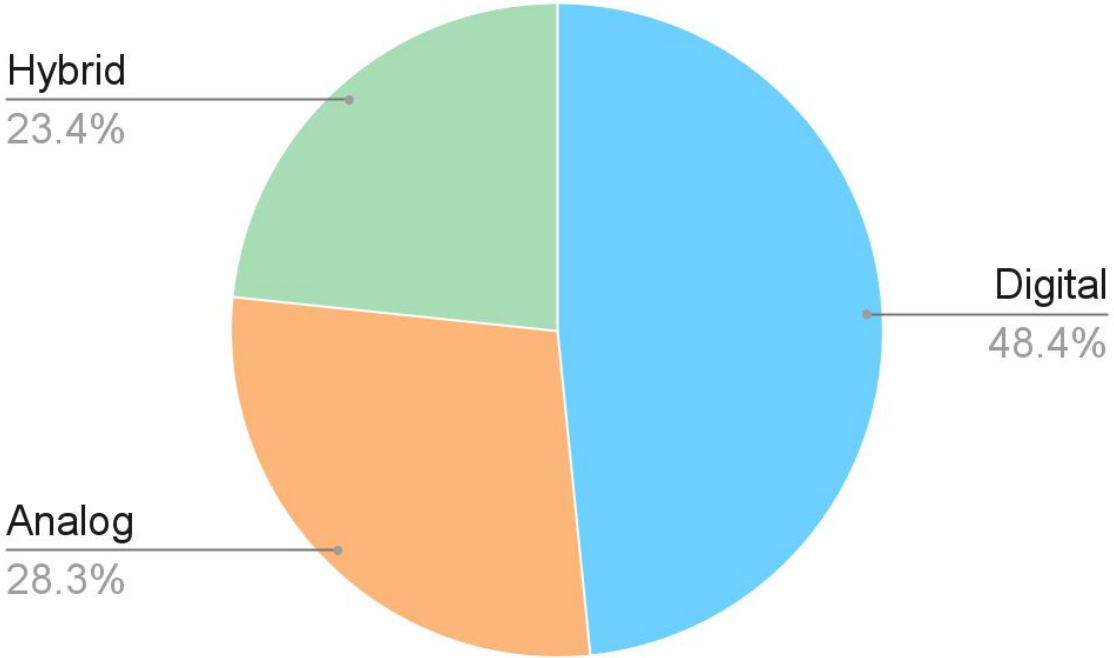
Pre-Study: Common Proportion Representations



Facer Top 100 List

Review 400 top watch faces (184 unique)

How does time display on the top watch faces?



What are common ways for representing proportions?

153 unique watch faces with at least one proportion

Proportion Representations Design Space

	rectilinear			circular						
	 bar	 disc. bar	 bar w/i icon	 arc	 disc. arc	 donut	 disc. donut	 pie	 gauge	 sliding
calories					1					
distance					1					1
heart rate				1	2		1		5	1
steps	6	3		8	3	2	4	2	10	5
humidity						3				
phone bat.		1		3	2		1		3	1
watch bat.	10	7	13	11	5	2	8	2	26	4
Sum	16	11	13	23	14	7	14	4	44	12

Watch Face Design

Visualization Representations to Compare

A common rectilinear construction

40 times

	rectilinear			circular						
	bar	disc. bar	bar w/i icon	arc	disc. arc	donut	disc. donut	pie	gauge	sliding
calories					1					
distance					1					1
heart rate				1	2		1		5	1
steps	6	3		8	3	2	4	2	10	5
humidity						3				
phone bat.		1		3	2		1		3	1
watch bat.	10	7	13	11	5	2	8	2	26	4
Sum	16	11	13	23	14	7	14	4	44	12

A common circular construction

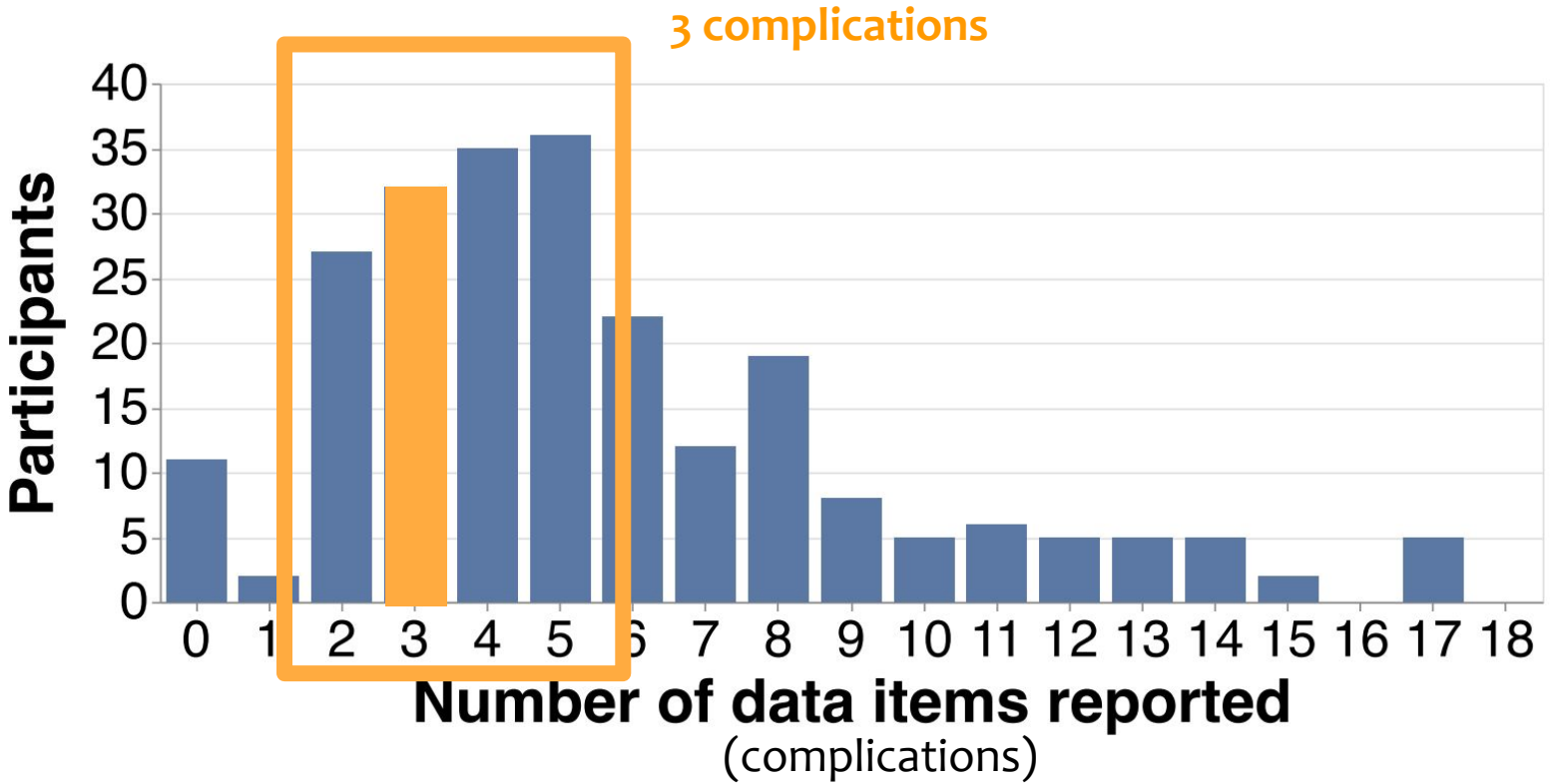
21 times

Visualization Representations to Compare

Bar Chart

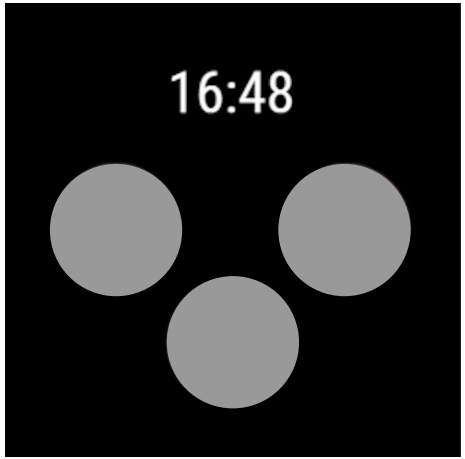
Radial Bar Chart

Number of Complications



[Islam et al., 2020]

Location of the Complications



Final Design

Study Design

Data for Stimuli

- 3 complications (proportions)
- Among them, 1, 2, or 3 complications show **a proportion above 66%**

Task

How many complications represent a proportion larger than 66%?

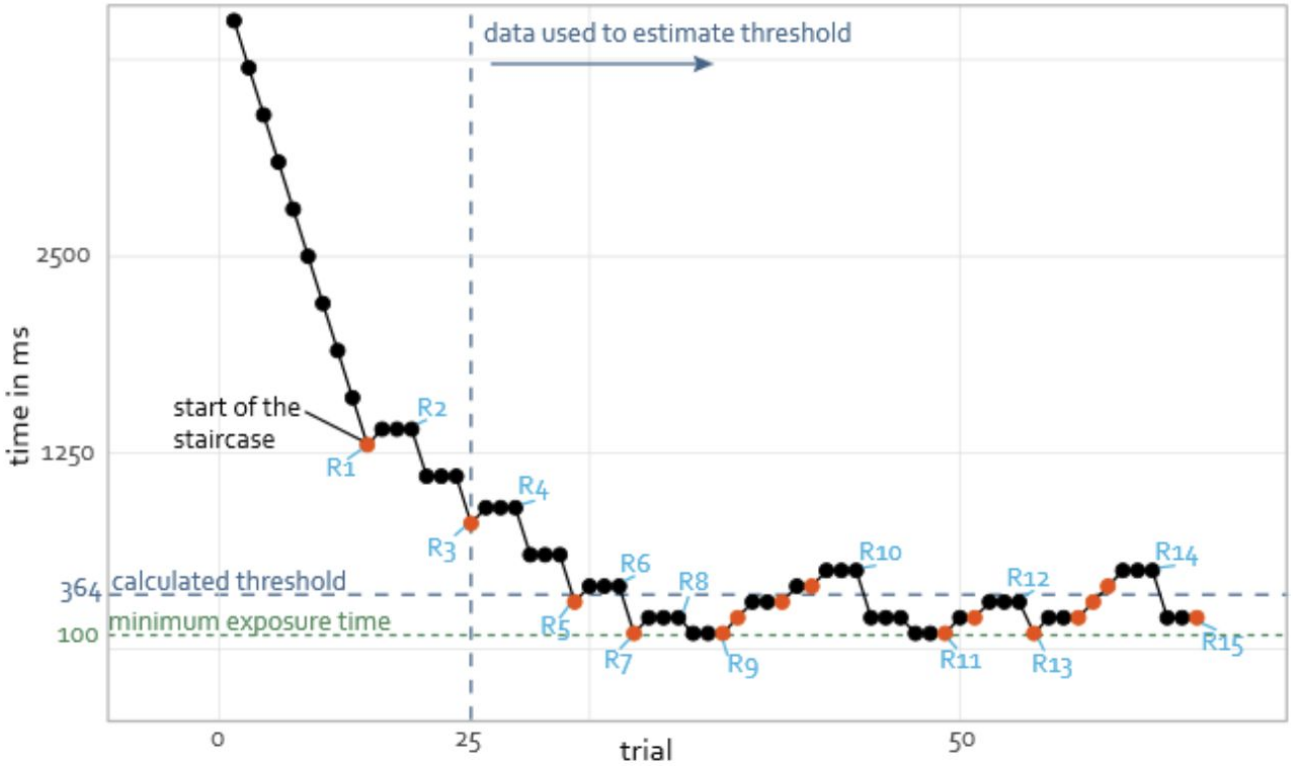
1 2 3

Task

How many complications represent a proportion larger than 66%?

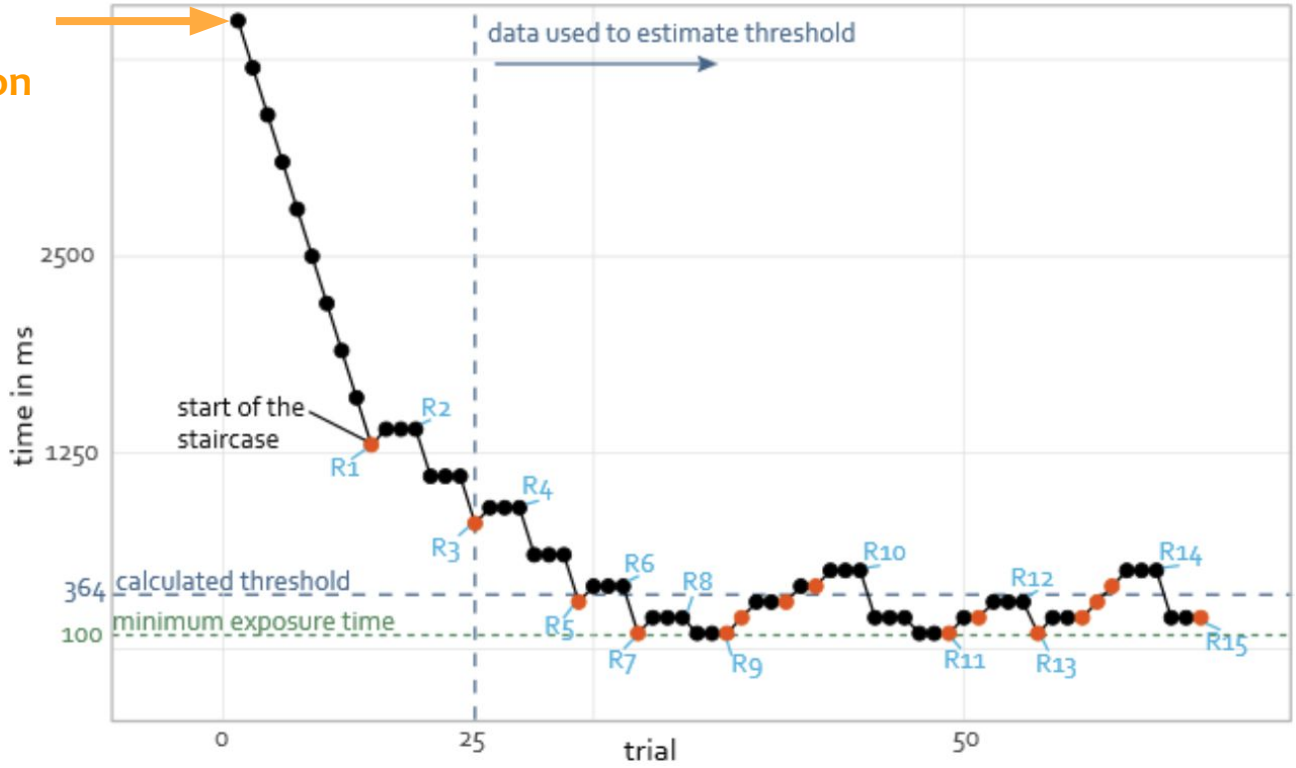
1 | 2 | 3

Stimulus Exposure Duration: Staircase Procedure



Stimulus Exposure Duration: Staircase Procedure

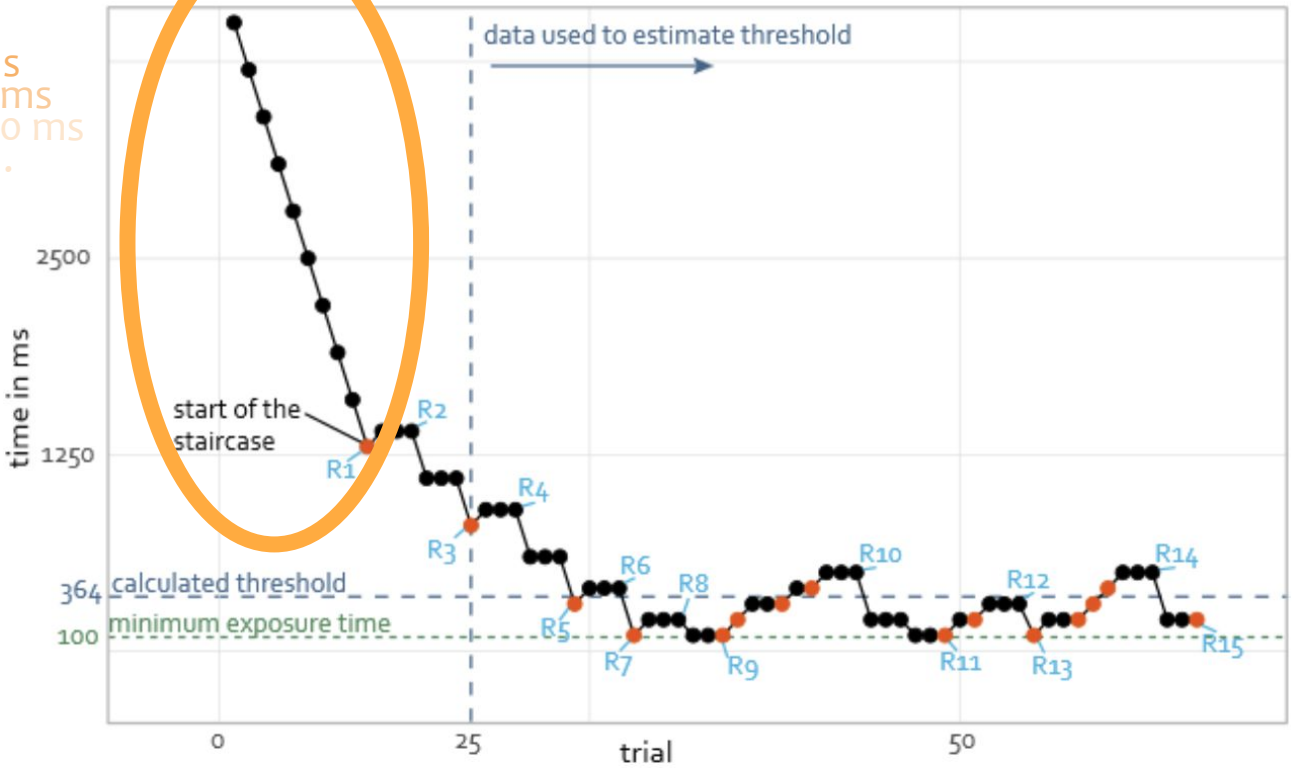
started with a certain duration



Stimulus Exposure Duration: Staircase Procedure

Each correct response

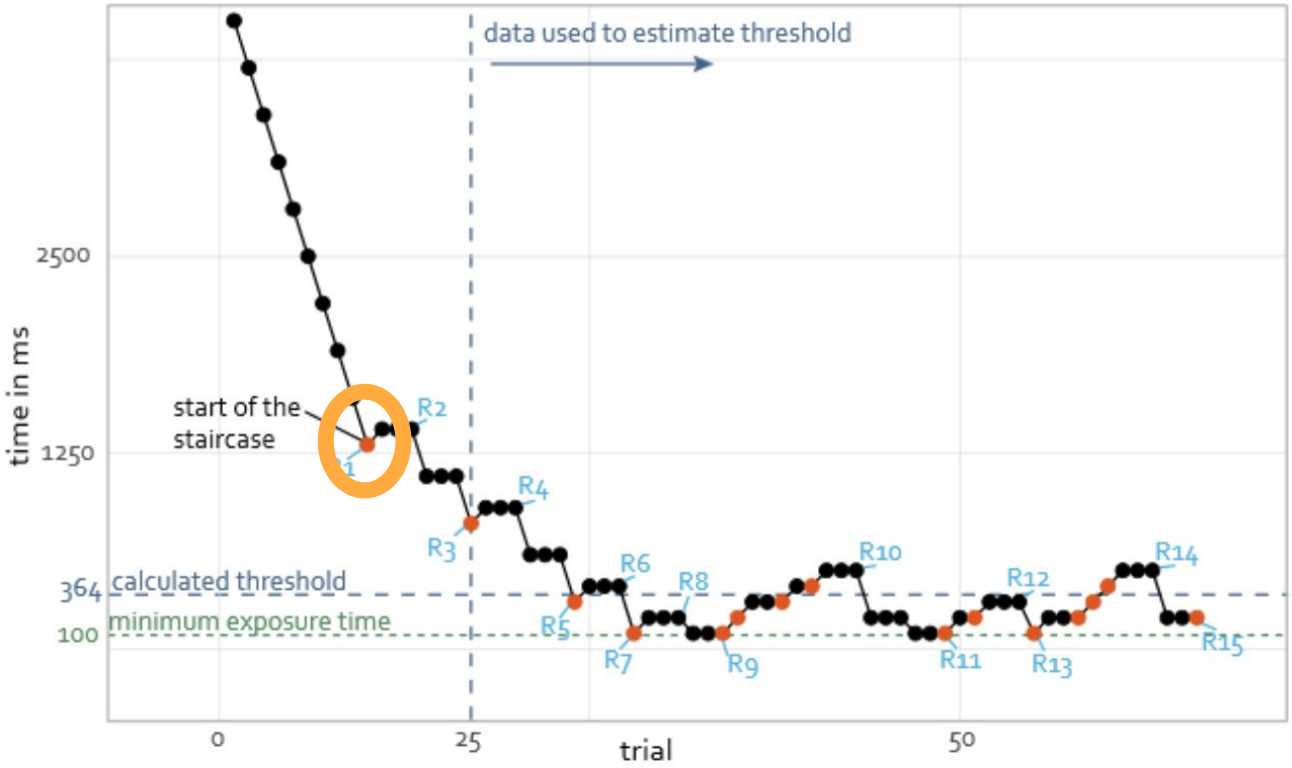
-200 ms
-200 ms
-200 ms
-200 ms
...



Stimulus Exposure Duration: Staircase Procedure

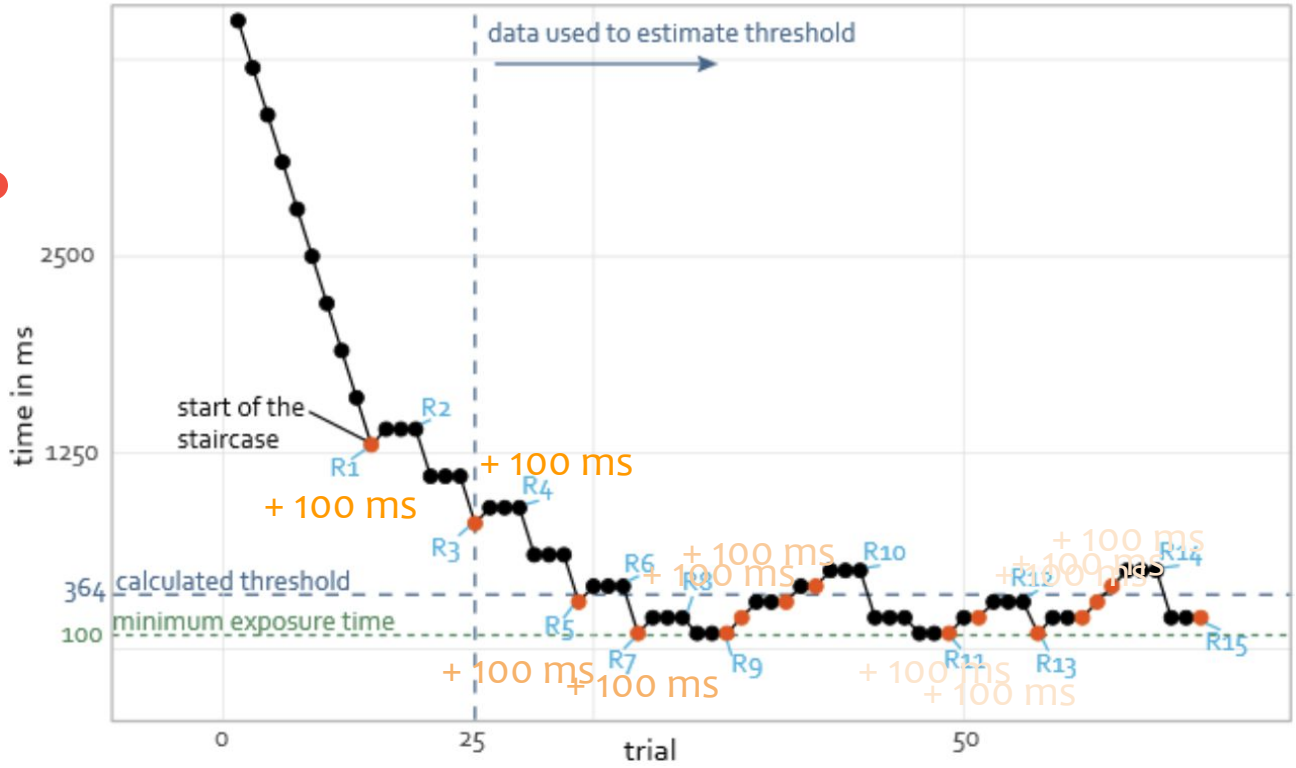
First mistake

+ 100 ms



Stimulus Exposure Duration: Staircase Procedure

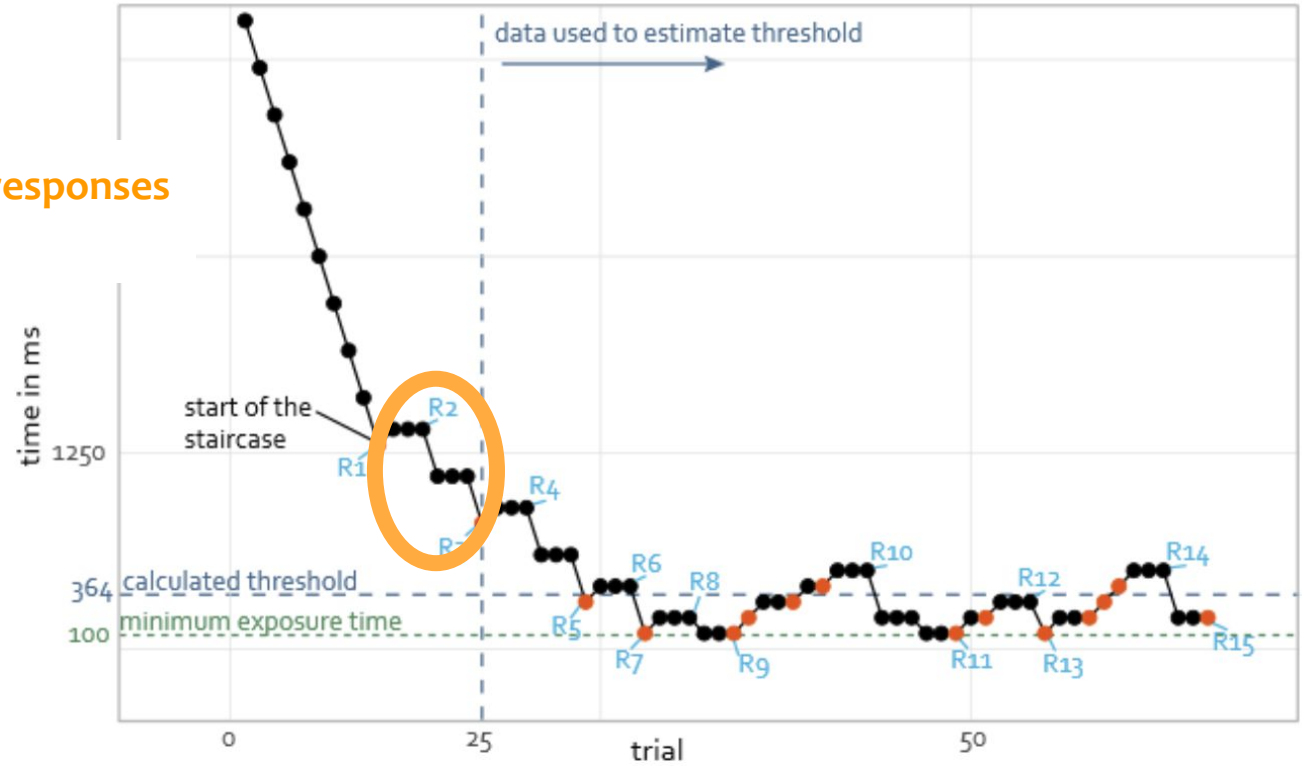
Each mistake ●



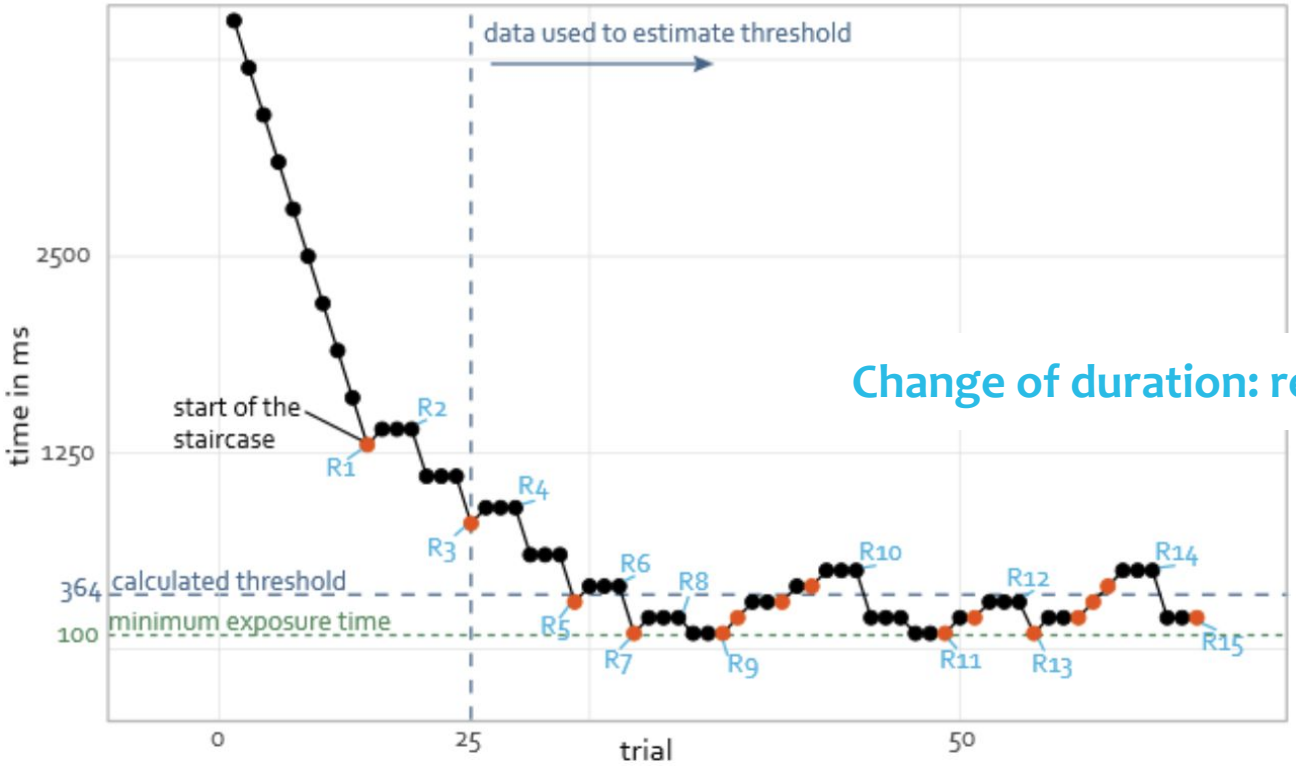
Stimulus Exposure Duration: Staircase Procedure

three correct responses in a row

-200 ms



Stimulus Exposure Duration: Staircase Procedure



Change of duration: reversals (R)

Procedure for One Condition

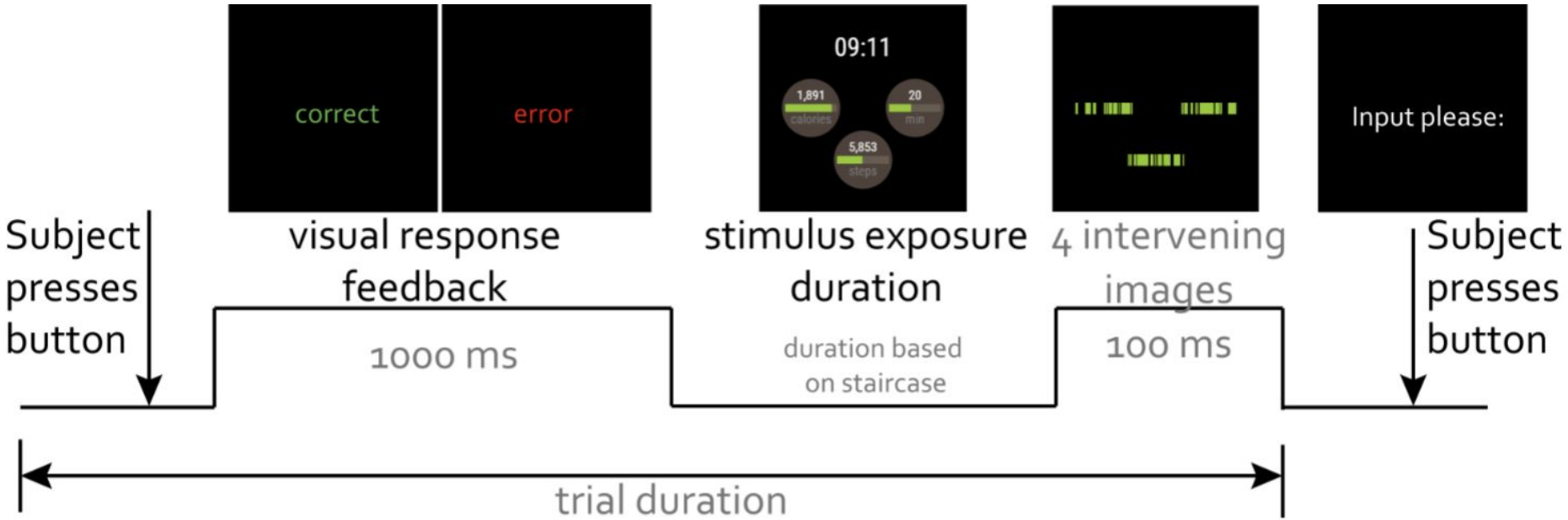
10 Training trials → Condition → Termination criteria

Starting time for each staircase: 1000 ms

One of the two:

- 25 reversals, or
- 180 trials

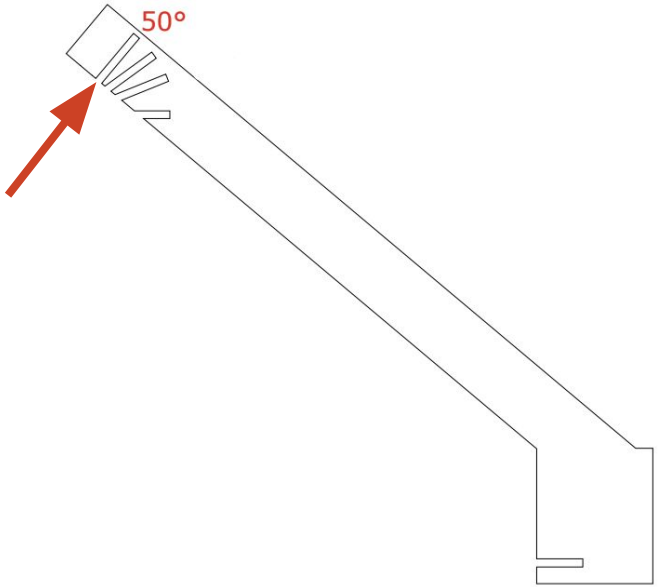
Procedure for One Trial



1.5 ~ 2 seconds

Apparatus

Attached a smartwatch to a self-designed adjustable stand, at an angle of 50°
[Blascheck et al., 2018; Blascheck et al., 2019]



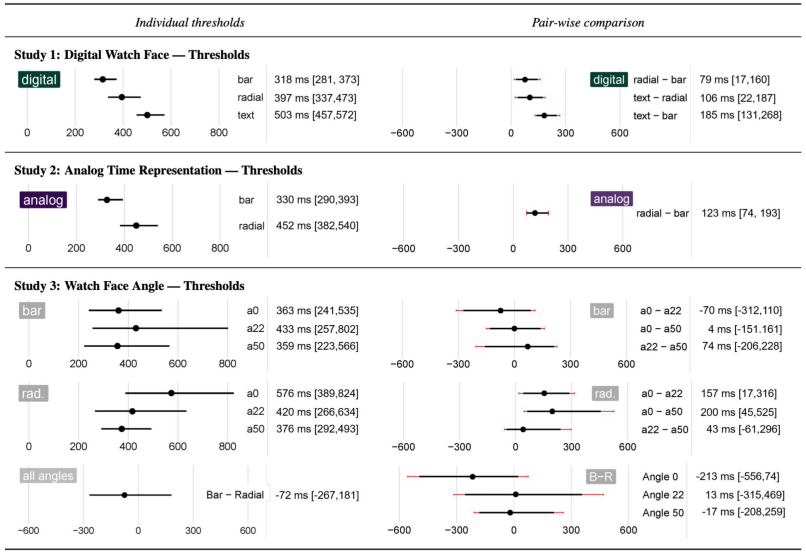
- Smartwatch at a height of 110 cm from the floor
- Viewing distance of 28 cm from the seated participant

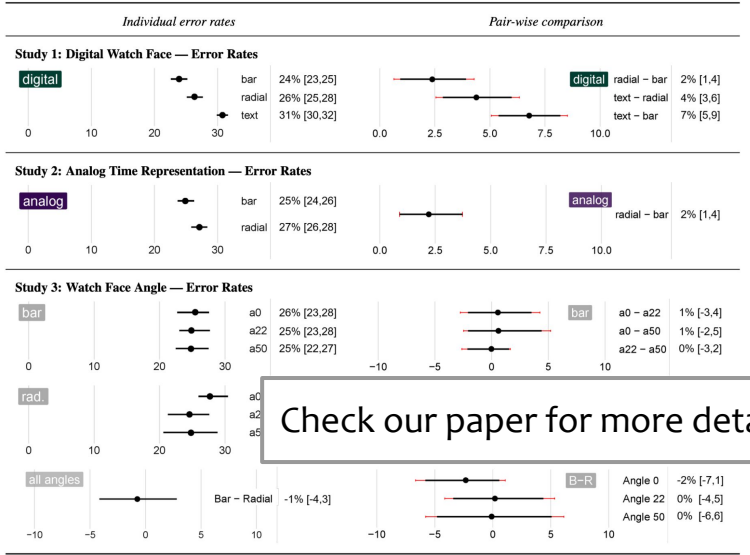
Measure

- Time threshold
- Error rate
- Participants’ rankings of techniques

Data Analysis and Interpretation

- Mean with 95% confidence interval (CI)
- Pairwise comparison of different technologies with 95% CI and Bonferroni correction





Check our paper for more details

3 Perceptual Studies

Started from a simplest watch face

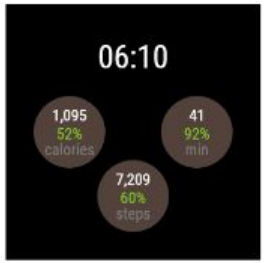
Study 1: Digital Watch Face

- 3 representations
- 30 participants

70%

Study 1: Results

Speed & Accuracy



503ms , 31% error

397ms , 26% error

318ms, 24% error

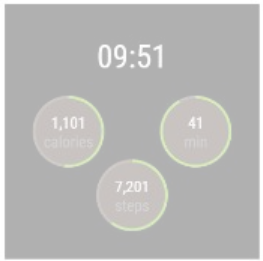
Worst

Best

Study 1: Results

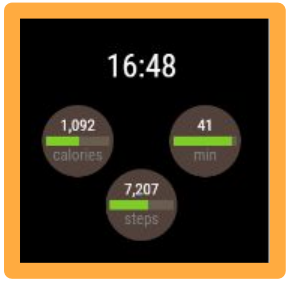
Speed & Accuracy

503ms , 31% error



397ms , 26% error

Best

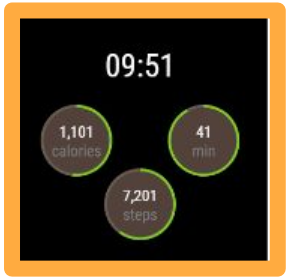


318ms, 24% error

Study 1: Results

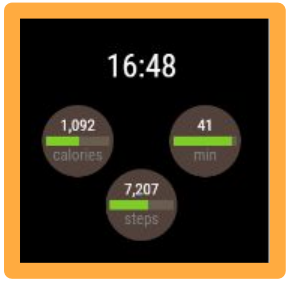
Speed & Accuracy

503ms , 31% error



397ms , 26% error

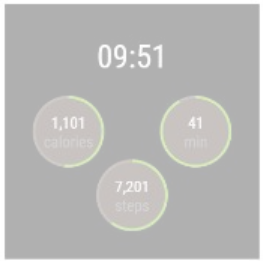
Difference is very small



318ms, 24% error

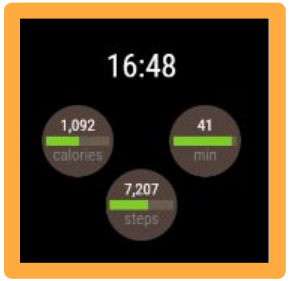
Study 1: Results

Ranking



Most **confident**

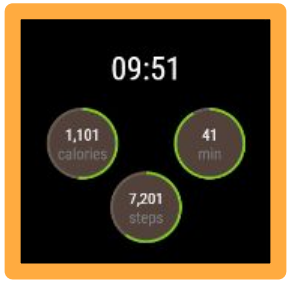
Most **efficient**



Study 1: Results

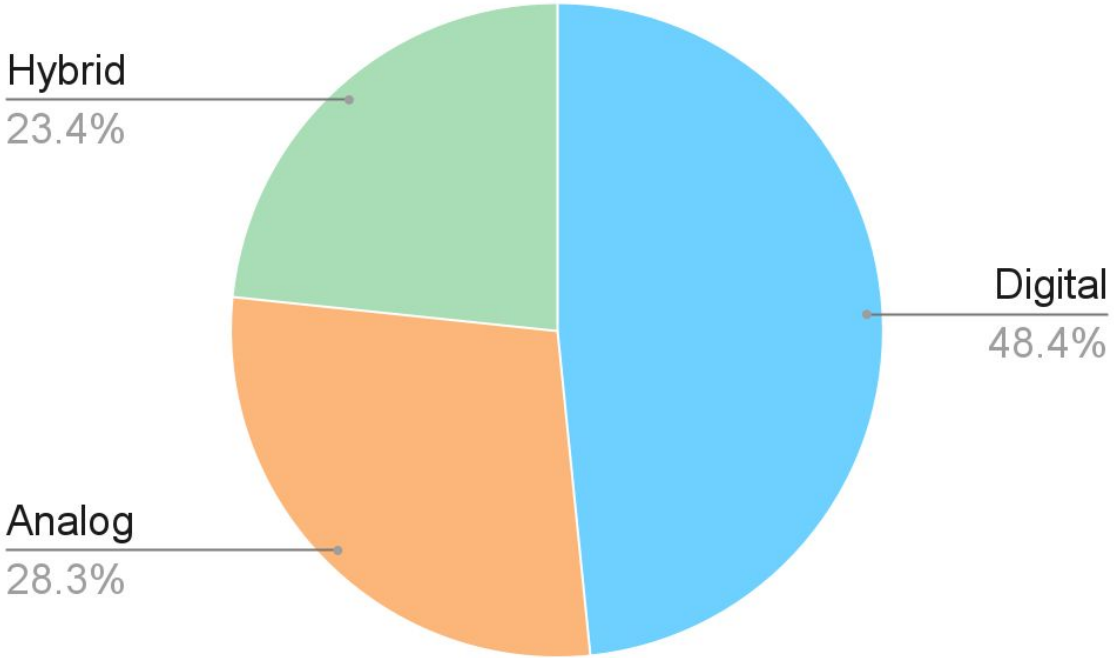
Ranking

Most **visually pleasing**



A more complex watchface?

Analog representation is common on real watch faces



Study 2: Adding an Analog Time Representation

- 2 representations 
  - removed the text **70%**: poor performance and lowest ranking
- 30 participants

Study 2: Results

Speed & Accuracy

452ms, 25% error

+55ms

330ms, 27% error

+12ms

Study 2: Results

Speed & Accuracy

452ms, 25% error
+55ms

Faster

330ms, 27% error
+12ms

Study 2: Results

Speed & Accuracy

Fewer errors

(Difference is very small)

452ms, 25% error

+55ms

330ms, 27% error

+12ms

Study 2: Does an analog watch face distract?

452ms, 25% error

+55ms

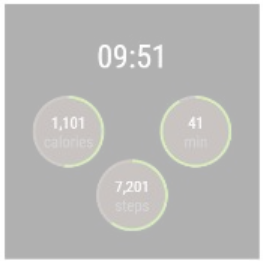
Not really

330ms, 27% error

+12ms

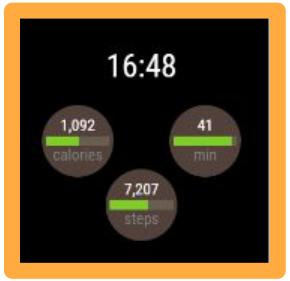
Study 2: Results

Ranking



Most **confident**

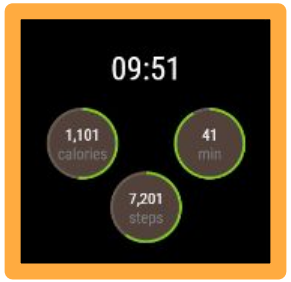
Most **efficient**



Study 2: Results

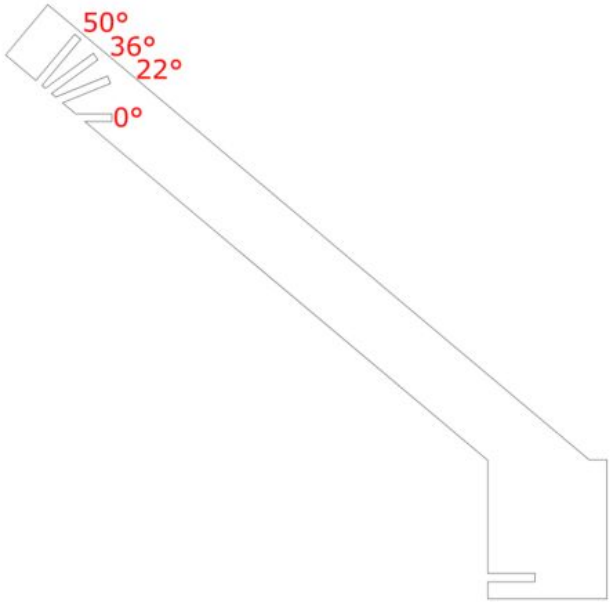
Ranking

Most **visually pleasing**



Not everyone views their watch from the same angle…

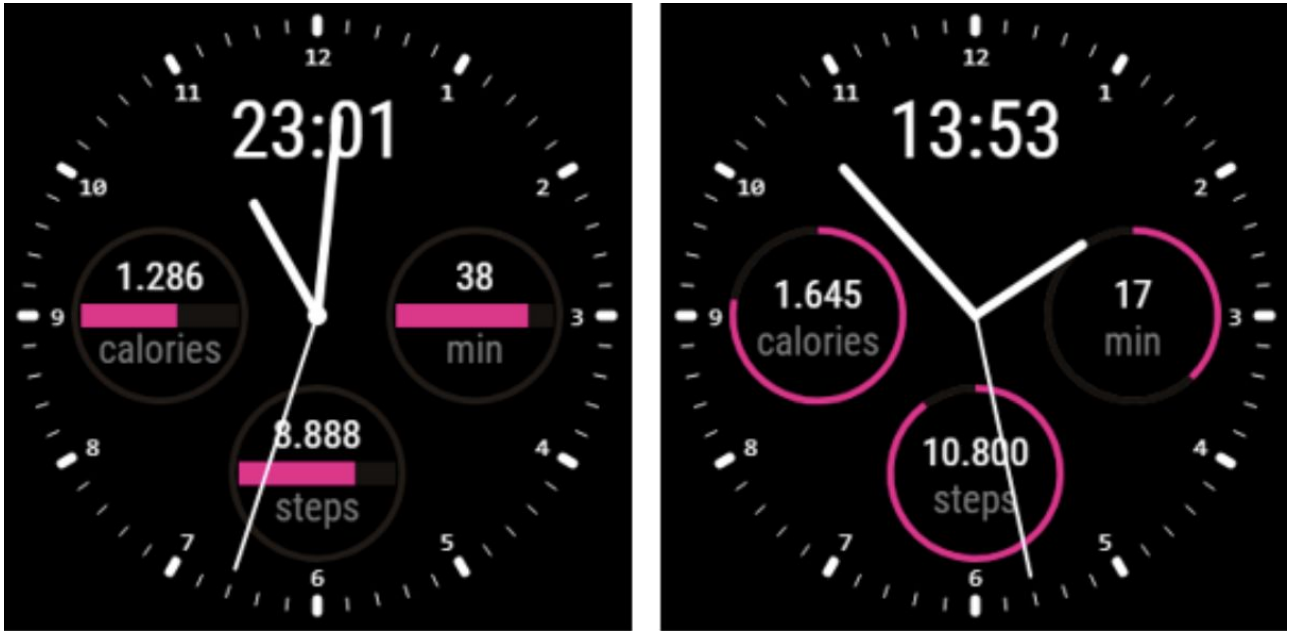
Study 3: Impact of Viewing Angle



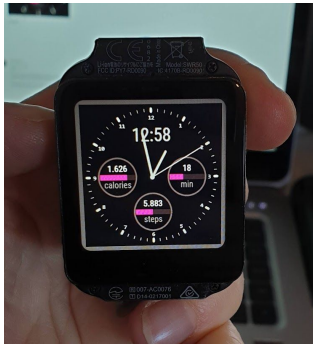
- 2 representations 
- 14 participants

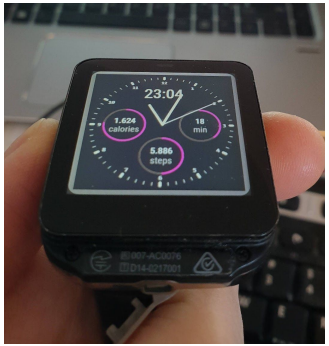
Study 3: Representations

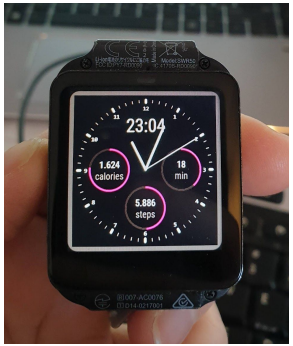
Between-subject design: **Bar** and **Radial**

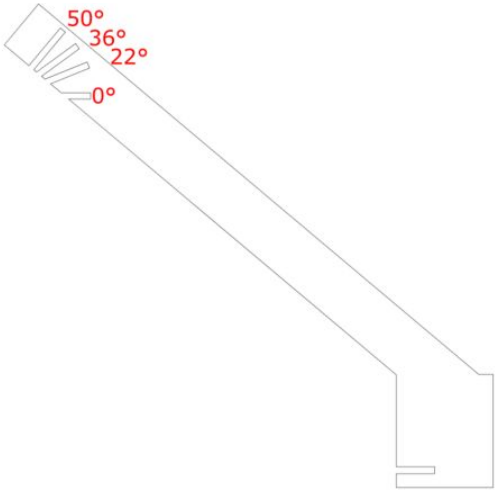


Study 3: Viewing Angles









- **50°**: average viewing angle of a worn watch
  [Blascheck et al., 2018; Blascheck et al., 2019]
- **0°**: an extreme case
- **22°**: Roughly in the middle between 0° and 50°; 2 SD from the average angle

- **36°**: 1 SD from the average angle - used for training

Design Modification due to 0° Issue

- Bright magenta
- Remove the background of the complication
- Desaturated the complication border

Study 3: Results - **Bar**

Speed & Accuracy

No evidence of a difference for different viewing angles.

0° - 363ms, 26%

22° - 433ms, 25%

50° - 359ms, 25%

Study 3: Results - **Radial**

Speed & Accuracy

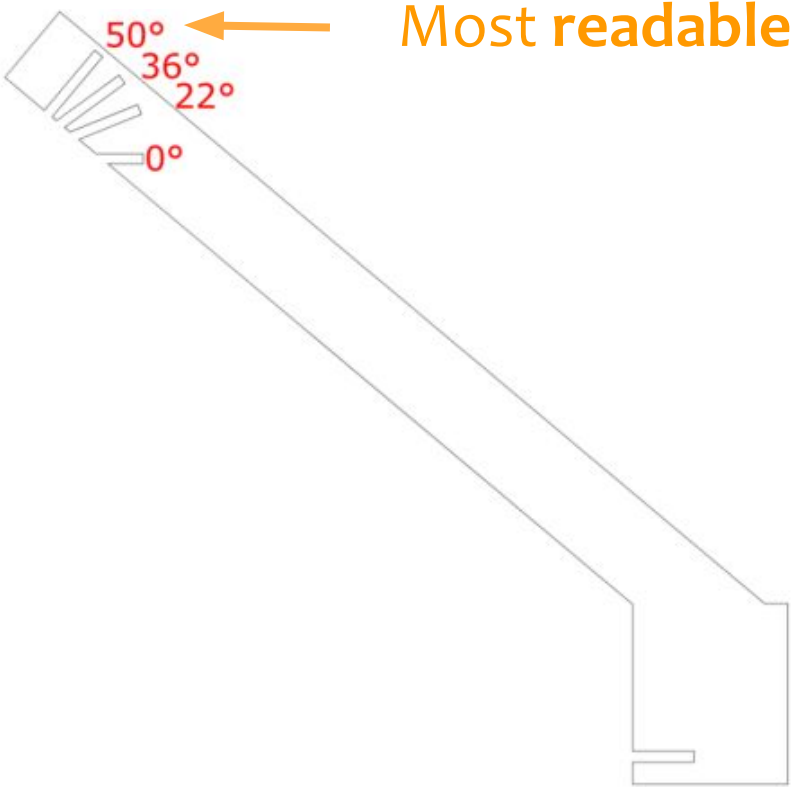
Slower & more error at 0°, but differences are practically small

0° - 576ms, 28%

22° - 420ms, 25%

50° - 376ms, 25%

Study 3 Results: Ranking of Readability



Most **readable**

RK	50°	22°	0°
1	10	3	1
2	2	11	1
3	2	0	12

What did we learn about reading multiple proportions at once?

- Multiple proportions can be **quickly assessed** (<500ms)
  - `Bar` charts and `Radial` bar charts perform better than `Text`
- The **analog watch display** only has a small impact on performance
- The **viewing angle** matters only slightly

Conclusion: That's good news!

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Thank You

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