

## Mathematics of Experimentation (Additional File)

### Worked Example of Accuracy and Precision

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*A medical student (she just started her clerkship in pediatrics) and a professional anthropometrist, both took MUAC (mid-upper-arm circumference) of right arm of a 7-year-old girl. The data are given below. By computing accuracy and precision, identify medical student/anthropometrist (measurer  $M_1$  or  $M_2$ ) — reference value of MUAC is 16.5 cm.*

Table 1. Accuracy and precision computation of measurer  $M_1$  (reference value,  $R = 16.5$  cm)

$i$	$O_i$ (cm)	$ O_i $ (cm)	$(O_i - \bar{O})$ (cm)	$ O_i - \bar{O} $ (cm)	$(O_i - R)$ (cm)	$ O_i - R $ (cm)
1	16.4	16.4	-0.26	0.26	-0.1	0.1
2	16.3	16.3	-0.36	0.36	-0.2	0.2
3	16.7	16.7	0.04	0.04	0.2	0.2
4	16.8	16.8	0.14	0.14	0.3	0.3
5	17.1	17.1	0.44	0.44	0.6	0.6
$\Sigma$	83.3	83.3		1.24		1.4

Accuracies ( $A$ ) and precisions ( $P$ ) of measurers  $M_1$  and  $M_2$  are computed in Tables 1 and 2, respectively.

$$\text{Measurer } M_1: \bar{O} = \frac{1}{N} \sum_{i=1}^N O_i = \frac{83.3}{5} = 16.66 \text{ cm} \cdot \overline{|O|} = \frac{83.3}{5} = 16.66 \text{ cm}$$

$$D = \sum_{i=1}^N \frac{|O_i - \bar{O}|}{N-1} = \frac{1.24}{4} = 0.31 \text{ cm} \cdot D_R = \sum_{i=1}^N \frac{|O_i - R|}{N-1} = \frac{1.4}{4} = 0.35 \text{ cm}$$

$$A = 100 \left[ 1 - \frac{D_R}{D_R + \overline{|O|}} \right] = 97.942386832\% \cdot P = 100 \left[ 1 - \frac{D}{D + \overline{|O|}} \right] = 98.173246907\%$$

$$\text{Measurer } M_2: \bar{O} = \frac{1}{N} \sum_{i=1}^N O_i = \frac{82.5}{5} = 16.5 \text{ cm} \cdot \overline{|O|} = \frac{82.5}{5} = 16.5 \text{ cm}$$



**Measuring MUAC of a 7-year-old girl**

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Table 2. Accuracy and precision computation of measurer  $M_2$  (reference value,  $R = 16.5 \text{ cm}$ )

$i$	$O_i \text{ (cm)}$	$ O_i  \text{ (cm)}$	$(O_i - \bar{O}) \text{ (cm)}$	$ O_i - \bar{O}  \text{ (cm)}$	$(O_i - R) \text{ (cm)}$	$ O_i - R  \text{ (cm)}$
1	16.5	16.5	0.0	0.0	-0.1	0.1
2	16.6	16.6	0.1	0.1	-0.2	0.2
3	16.4	16.4	-0.1	0.1	0.2	0.2
4	16.6	16.6	0.1	0.1	0.3	0.3
5	16.4	16.4	-0.1	0.1	0.6	0.6
$\Sigma$	82.5	82.5		0.4		0.4

$$D = \sum_{i=1}^N \frac{|O_i - \bar{O}|}{N-1} = \frac{0.4}{4} = 0.1 \text{ cm} \bullet D_R = \sum_{i=1}^N \frac{|O_i - R|}{N-1} = \frac{0.4}{4} = 0.1 \text{ cm}$$

$$A = 100 \left[ 1 - \frac{D_R}{D_R + |\bar{O}|} \right] = 99.397590362\% \bullet P = 100 \left[ 1 - \frac{D}{D + |\bar{O}|} \right] = 99.397590362\%$$

A comparative statement is prepared in Table 3, which shows that measurer  $M_2$  has not only *higher precision* — indicator of good work habits, 99.397590362% as compared to 98.173246907% (measurer  $M_1$ ), but also *higher accuracy* — indicator of accessibility to good instruments, 99.397590362% as compared to 97.942386832% (measurer  $M_1$ ). According to these results, measurer  $M_2$  seems to be *professional anthropometrist*, whereas measurer  $M_1$  looks like *medical student*.

In case, the professional anthropometrist forgot his glasses on the day of measurement, his precision should have been higher, but accuracy might have dropped.

Please note that mean deviation ( $D$ ) is used instead of standard deviation ( $\sigma$ ) as the data are not normally distributed (number of observations being only 5).

Table 3. Accuracies and precisions of measurers  $M_1$  and  $M_2$

	<i>Accuracy</i>	<i>Precision</i>
Measurer $M_1$	97.942386832%	98.173246907%
Measurer $M_2$	99.397590362%	99.397590362%

*Web address of the main document:*

**Prof. Dr. Muhammed Rafi and Prof. Dr. Razi Hussin Memorial Lecture: Mathematics of Experimentation**  
<http://www.ngds-ku.org/Presentations/Physics2.pdf>

*Web address of this document:*

**Additional File (Mathematics of Experimentation): Worked example of Accuracy and Precision**  
[http://www.ngds-ku.org/Presentations/Physics2/Additional\\_File.pdf](http://www.ngds-ku.org/Presentations/Physics2/Additional_File.pdf)