VIP Cheatsheet: Statistics

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Parameter estimation

❒ **Random sample** – A random sample is a collection of n random variables $X_1, ..., X_n$ that are independent and identically distributed with X.

❒ **Estimator** – An estimator $\hat{\theta}$ is a function of the data that is used to infer the value of an unknown parameter θ in a statistical model.

❒ **Bias** – The bias of an estimator $\hat{\theta}$ is defined as being the difference between the expected value of the distribution of $\hat{\theta}$ and the true value, i.e.:

$$\text{Bias}(\hat{\theta}) = E[\hat{\theta}] - \theta$$

Remark: an estimator is said to be unbiased when we have $E[\hat{\theta}] = \theta$.

❒ **Sample mean and variance** – The sample mean and the sample variance of a random sample are used to estimate the true mean μ and the true variance σ^2 of a distribution, are noted $\overline{X}$ and s^2 respectively, and are such that:

$$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \quad \text{and} \quad s^2 = \hat{\sigma}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \overline{X})^2$$

❒ **Central Limit Theorem** – Let us have a random sample $X_1, ..., X_n$ following a given distribution with mean μ and variance σ^2, then we have:

$$\overline{X}_{n\rightarrow\infty} \sim N\left(\mu, \frac{\sigma}{\sqrt{n}}\right)$$

Confidence intervals

❒ **Confidence level** – A confidence interval $CI_{1-\alpha}$ with confidence level $1-\alpha$ of a true parameter θ is such that $1-\alpha$ of the time, the true value is contained in the confidence interval:

$$P(\theta \in CI_{1-\alpha}) = 1 - \alpha$$

❒ **Confidence interval for the mean** – When determining a confidence interval for the mean μ, different test statistics have to be computed depending on which case we are in. The following table sums it up:

Distribution	Sample size	σ^2	Statistic	$1-\alpha$ confidence interval
$X_i \sim N(\mu, \sigma)$	any	known	$\frac{\overline{X}-\mu}{\frac{\sigma}{\sqrt{n}}} \sim N(0,1)$	$\left[\overline{X} - z_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}}, \overline{X} + z_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}}\right]$
	small	unknown	$\frac{\overline{X}-\mu}{\frac{s}{\sqrt{n}}} \sim t_{n-1}$	$\left[\overline{X} - t_{\frac{\alpha}{2}}\frac{s}{\sqrt{n}}, \overline{X} + t_{\frac{\alpha}{2}}\frac{s}{\sqrt{n}}\right]$
$X_i \sim$ any	large	known	$\frac{\overline{X}-\mu}{\frac{\sigma}{\sqrt{n}}} \sim N(0,1)$	$\left[\overline{X} - z_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}}, \overline{X} + z_{\frac{\alpha}{2}}\frac{\sigma}{\sqrt{n}}\right]$
		unknown	$\frac{\overline{X}-\mu}{\frac{s}{\sqrt{n}}} \sim N(0,1)$	$\left[\overline{X} - z_{\frac{\alpha}{2}}\frac{s}{\sqrt{n}}, \overline{X} + z_{\frac{\alpha}{2}}\frac{s}{\sqrt{n}}\right]$
$X_i \sim$ any	small	any	Go home!	Go home!

❒ **Confidence interval for the variance** – The single-line table below sums up the test statistic to compute when determining the confidence interval for the variance:

Distribution	Sample size	μ	Statistic	$1-\alpha$ confidence interval
$X_i \sim N(\mu, \sigma)$	any	any	$\frac{s^2(n-1)}{\sigma^2} \sim \chi^2_{n-1}$	$\left[\frac{s^2(n-1)}{\chi^2_1}, \frac{s^2(n-1)}{\chi^2_2}\right]$

Hypothesis testing

❒ **Errors** – In a hypothesis test, we note α and β the type I and type II errors respectively. By noting T the test statistic and R the rejection region, we have:

$$\alpha = P(T \in R | H_0 \text{ true}) \quad \text{and} \quad \beta = P(T \notin R | H_1 \text{ true})$$

❒ **p-value** – In a hypothesis test, the p-value is the probability under the null hypothesis of having a test statistic T at least as extreme as the one that we observed T_0. In particular, when T follows a zero-centered symmetric distribution under H_0, we have:

Case	Left-sided	Right-sided	Two-sided
p-value	$P(T \leqslant T_0 | H_0 \text{ true})$	$P(T \geqslant T_0 | H_0 \text{ true})$	$P(|T| \geqslant |T_0| | H_0 \text{ true})$

❒ **Sign test** – The sign test is a non-parametric test used to determine whether the median of a sample is equal to the hypothesized median. By noting V the number of samples falling to the right of the hypothesized median, we have:

Statistic when $np < 5$	Statistic when $np \geqslant 5$
$V \sim_{H_0} B\left(n, p = \frac{1}{2}\right)$	$Z = \frac{V - \frac{n}{2}}{\frac{\sqrt{n}}{2}} \sim_{H_0} N(0,1)$

❒ **Testing for the difference in two means** – The table below sums up the test statistic to compute when performing a hypothesis test where the null hypothesis is:

$$H_0 \quad : \quad \mu_X - \mu_Y = \delta$$

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