Research Methods & Technical Writing

Lesson 3 - Week 3

Research Design

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Flashback from Lesson 2

- The research problem can be defined as "a general educational issue, concern, or controversy addressed in research that narrows the topic".
- A key requirement in the determination of the research problem (question) is clarity in the research objectives and a precise definition of the problem.
- According to the identified research problems one may speak of exploratory, comparative, diachronic and explanatory researches.
- The definition of the problem sets the direction of the study, reveals the approach (methodology) of the study, helps the investigator control his/her bias or subjectivity, specifies the variables that need investigation since they will be included in the problem definition, and makes the research work practicable.
- The steps in order of defining a research problem are: General research problem statement, understand nature of the problem, literature survey, develop ideas through discussions (brainstorming), and rephrase research problem into working proposition

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- Introduction
- Research design defined
- Characteristics of research design
- Features of a good design
- Research design concepts
- Research designs
- Principles of experimental design

Part 1

Introduction

Introduction

- In lesson 2 we discussed the importance of the research problem to the overall research process. To summarize it, you can't solve a problem unless you have clearly defined what it is in the first place.
- Once the problem is clear, then and only then, can you go about devising ways of investigating and consequently solving it.
- In the bricks world as we call it, our brain is constantly working on solving different day to day problems. For example, on the first day of college you find that you got to class late for your first lecture. This presents a problem, especially since you're a keen student. You figure out that this means you will need to get to the bus stop earlier the next day. Next day you find that you still arrive late for the lecture, despite having made it to the bus stop 15 minutes before the first day. Ok, more adjustments required.
- You will make these adjustments until you get it right. Once you get it right, chances are you will fall into a routine that ensures you get to college in time. This could mean something like: wake up by 0600 hrs, shower and dress by 0630 hrs, breakfast by 0700 hrs, bus stop by 0730 hrs, college gate by 0830 hrs, walk to the lecture hall and be in class by 0850 hrs in time for the 0900 hrs lecture. Using this approach you can even share it with your next door neighbor Pete who also appear to be struggling to get to class on time.

Introduction (cont'd)

- The approach you used and shared is a tested (albeit through many trials and errors ☺) one and it works. Over time you share it with friends, they make a few custom adjustments, but they all agree it works and adopt it.
- They even give it a name: Jay's approach, aptly named after you.
- Enter research design. What we've just described is what research design entails. It is a way of describing the what, when, where and how of the problem that you clearly defined in lesson 2.
- 'What' describes the problem; when, where and how describes the way in which the problem will be solved. Research design describes the way in which you will go about solving the problem in a systematic, proven way.
- A research design also called a research strategy, is a plan to answer a set of questions (McCombes, 2019, as cited by Bouchrika, 2022).

Introduction (cont'd)

- "It is a framework that includes the methods and procedures to collect, analyze, and interpret data. In other words, the research design describes how the researcher will investigate the central problem of the research…" (Bouchrika, 2022)
- This lesson describes various aspects of research design, from defining research design, discussing the characteristics and features of good design, to describing some research designs.

Part 2

Research design defined

2.1 Introduction

- Research design was defined in part 1 of this lesson. Kothari (2004) goes further to add that "the design includes an outline of what the researcher will do from writing the hypothesis and its operational implications to the final analysis of data."
- The design decisions will happen with regards to the following (Kothari, 2004):
  - What is the study about?
  - Why is the study being made?
  - Where will the study be carried out?
  - What type of data is required?
  - Where can the required data be found?
  - What periods of time will the study include?
  - What will be the sample design?
  - What techniques of data collection will be used?
  - How will the data be analyzed?
  - In what style will the report be prepared?

2.2 Elements of research design

- There are many elements that make up a good research design. However, the most essential elements are (Leverage Edu, 2021):"
  - The method applied for analyzing collected details
  - Type of research methodology
  - Accurate purpose statement
  - Probable objections to research
  - Techniques to be implemented for collecting and analyzing research
  - Timeline
  - Measurement of analysis
  - Settings for the research study"

2.3 Research design parts

- Based on the design decisions the overall research design can be split into three components/parts (Kothari, 2004):
- Sampling design – this is the one that will deal with how to select what will be observed for the given study
- Observational design – this deals with the conditions under which observations will be made.
- Operational design – deals with the approach that will be used to carry out the different methods specified in the sampling, statistical and observational designs.

2.4 Types of research design

- Research design can be viewed or described as being one of two perspectives:
- Quantitative design: this comes from the word "quantity". Mathematically quantities are measured using numbers, and this is what quantitative design is all about. This type of design uses numbers to collect data, and statistics to analyze the findings. The data are measured and interpreted using figures and different types of charts.
- Qualitative design: this is derived from the word "quality". It is focused mostly on explanatory concepts, such as trying to explain certain theory or phenomena. Qualitative design involves asking respondents to answer questions that might shed light on the theory and phenomena; a common tool that is used is questionnaires with this type of design. Respondents might answer a question using a Likert scale for example (using "not likely" on the lower end and "definitely" on the higher end). Understandably qualitative design is mostly used in the social sciences in the form of case studies and so on.
- The choice of whether to use quantitative or qualitative type of research design is dependent of many factors such as the discipline (social sciences or STEM) and the phenomena being investigated. Table 1 describes the differences between qualitative and quantitative research design types.

Table 1. Qualitative and Quantitative design differences (Leverage Edu, 2021)

Quantitative Research	**Qualitative Research**
Focuses on putting ideas and hypotheses to the test. It is also known as fixed design	Concentrate on generating ideas and developing a theory or hypothesis. It is also known as flexible design
Math and statistical analysis were used to examine the situation.	Summarizing, classifying, and analyzing data were used to conduct the analysis.
Numbers, graphs, and tables are the most common forms of expression.	Mostly represented with words
It necessitates the participation of a large number of people.	Only a few people are required to answer.
Closed questions (multiple choice)	Open-ended inquiries
Key terms: testing, measurement, objectivity, replicability	Key terms: understanding, context, complexity, subjectivity

Part 3

Characteristics of research design

Characteristics of good research design

- (Bouchrika, 2022) describes the following as the characteristics of good research design: "
- **It is neutral.** Naturally, setting up a study comes with a measure of assumptions, which is why there is a hypothesis. However, good research design comes into play when the results obtained are as neutral and as objective as possible. It should allow the researcher to analyze and interpret the data that is free of any bias.
- **It is valid.** The design of the research also indicates the tools and techniques by which to measure results. If the design is sound, these tools will be correct and appropriate for the job, which will be defined as those that can help a researcher in measuring the results.
- **It is reliable.** Research design, when done well, can afford research that generates similar results every time it is performed. This means that a good research design creates an opportunity to form standards to collect and analyze results.
- **It can be generalized.** Generalized design means the design can apply not just to one part of a study, population, or setting. It should be able to cover any part with the same measure of accuracy."
- Fig 1 captures these characteristics summarily.

Fig 1. Characteristics of good research design (Leverage Edu, 2021)

Part 4

Characteristics of research design

4.1 Features of good design

- Unfortunately there is no one size fits all when it comes to research design. There are too many fluid parameters when it comes to this area; in fact two researchers may be studying phenomena in the same area of interest but they would have to apply different research designs in their quest for answers.
- However, Kothari (2004) opines that the following three features characterize good research design:
  - Minimizes bias and maximizes reliability of the data collected (and analyzed)
  - Gives the smallest experimental error (this is a best case scenario)
  - Yields maximum information and provides an opportunity for considering many different aspects of a problem

4.1 Features of good design (cont'd)

- Further, (indiafreenotes, 2023) also offers the following as features of good research design:
  - Clear research question
  - Adequate research methods
  - Clear and applicable sampling method
  - Good data analysis methods, and they should be linked to the research question
  - Consideration of ethical issues
  - Should be replicable by other researchers
  - Should be SMART

4.2 Other considerations

- All research designs are dependent on the nature of the research problem; hence the one size doesn't fit all adage. The design is dependent on so many factors, but the approach in most cases is the same; the difference lies in issues like the way data will be collected (the sampling approach), the analysis tools, whether a hypothesis will be used or not, and so on.
- Consequently, for a specific research problem, the following factors should be considered (Kothari, 2004):"
  - the means of obtaining information;
  - the availability and skills of the researcher and his staff, if any;
  - the objective of the problem to be studied;
  - the nature of the problem to be studied; and
  - the availability of time and money for the research work."

Part 5

Research design concepts

5.1 Variables

- Variable: A variable is a quantity that may change within the context of a mathematical problem or experiment. Typically, we use a single letter to represent a variable. (Nykamp, 2021); in other words a variable is something that can be measured. In research and mathematics a letter normally gives an idea of what the variable stands for; for example, time is usually represented by t, and so on. Other examples of variables in research include weight, height, diameter, age, and so on. There are different types of variables, but we shall mention the ones of interest to us in the context of research.
- The definitions that follow are all from (Government of Canada, 2002):
  - Categorical variable: A categorical variable (also called qualitative variable) refers to a characteristic that can't be quantifiable. Categorical variables can be either nominal or ordinal.
  - Nominal variable: is one that describes a name, label or category without natural order. Sex and type of dwelling are examples of nominal variables.
  - Ordinal variable: An ordinal variable is a variable whose values are defined by an order relation between the different categories. An example of an ordinal variable is education level ("primary", "high school", "undergraduate", "postgraduate")

5.1 Variables (cont'd)

- The definitions below are quoted from (Government of Canada, 2002):
- Numeric variable: A numeric variable (also called quantitative variable) is a quantifiable characteristic whose values are numbers (except numbers which are codes standing up for categories). Numeric variables may be either continuous or discrete.
  - Continuous variable: A variable is said to be continuous if it can assume an infinite number of real values within a given interval. For example, body temperature is a continuous variable, since even though the actual measurements might be rounded to the nearest whole number, in theory, there is some exact body temperature going out many decimal places.
  - Discrete variable: a discrete variable can assume only a finite number of real values within a given interval. An example of a discrete variable would be the score given by a judge to a gymnast in competition: the range is 0 to 10 and the score is always given to one decimal (e.g. a score of 8.5). You can enumerate all possible values (0, 0.1, 0.2…) and see that the number of possible values is finite: it is 101! Another example of a discrete variable is the number of people in a household for a household of size 20 or less. The number of possible values is 20, because it's not possible for a household to include a number of people that would be a fraction of an integer like 2.27 for instance. In other words a discrete variable is something you can count; the amount of money in your wallet is another good example.

5.2 Research & Statistical variables

- Having introduced general terms associated with variables, let us delve deeper into defining the types that are used in research and statistics. Table 2 defines dependent and independent variables, giving an example of each.

Table 2. Dependent and independent variables (Indeed Editorial Team, 2021).

	Independent Variable	Dependent Variable
Definition	A variable that stands alone and isn't changed by the other variables or factored that are measured	A variable that relies on and can be changed by other factors that are measured
Example	Age: Other variables such as where someone lives, what they eat or how much they exercise are not going to change their age.	A grade someone gets on an exam depends on factors such as how much sleep they got and how long they studied.

5.2 Research & Statistical variables (cont'd)

- Intervening vs moderating variables: An intervening variable, also known as a mediator or mediating variable, explains the process through which two variables are related, while a moderating, or moderator, variable affects the strength and direction of that relationship. (Indeed Editorial Team, 2021).
- An example of a moderating variable: There may be a relationship between socioeconomic status and how often women perform self-exams on their breasts. Age is possibly a **numerical** moderating variable: the relationship for socioeconomic status and breast self-exams might be weaker in younger women and stronger in older women. (Stephanie, 2014)
- Table 3 defines the two variables and gives examples of each.

Table 3. Intervening vs moderating variables (Indeed Editorial Team, 2021).

	Intervening Variables	Moderating Variables
Definition	A theoretical variable used to explain a cause or connection between other study variables	Changes the relationship between dependent and independent variables by strengthening or weakening the intervening variable's effect
Example	Access to health care: If wealth is the independent variable, and a long life span is a dependent variable, a researcher might hypothesize that access to quality health care is the intervening variable that links wealth and life span.	Age: If a study looking at the relationship between economic status (independent variable) and how frequently people get physical exams from a doctor (dependent variable), age is a moderating variable. That relationship might be weaker in younger individuals and stronger in older individuals.

5.2 Research & Statistical variables (cont'd)

- Indeed Editorial Team (2021) differentiate between extraneous and confounding variables as follows:"
- A confounding variable is a type of extraneous variable that is associated with both the independent and dependent variables.
- An extraneous variable is anything that could influence the dependent variable. These unwanted variables can unintentionally change a study's results or how a researcher interprets those results.
- A confounding variable influences the dependent variable, and also correlates with or causally affects the independent variable. Confounding variables can invalidate your experiment results by making them biased or suggesting a relationship between variables exists when it does not."
- Table 4 defines the extraneous variable and confounding variable, and provides examples of each.

Table 4. Extraneous vs confounding variables. (Indeed Editorial Team, 2021)

	Extraneous variables	Confounding variables
Definition	Factors that affect the dependent variable but that the researcher did not originally consider when designing the experiment	Extra variables that the researcher did not account for that can disguise another variable's effects and show false correlations
Example	Parental support, prior knowledge of a foreign language or socioeconomic status are extraneous variables that could influence a study assessing whether private tutoring or online courses are more effective at improving students' Spanish test scores.	In a study of whether a particular genre of movie affects how much candy kids eat, with experiments are held at 9 a.m., noon and 3 p.m. Time could be a confounding variable, as the group in the noon study might be hungrier and therefore eat more candy because lunchtime is typically at noon.

5.2 Research & Statistical variables (cont'd)

- Control: One important characteristic of a good research design is to minimize the influence or effect of extraneous variable(s). The technical term 'control' is used when we design the study minimizing the effects of extraneous independent variables. In experimental researches, the term 'control' is used to refer to restrain experimental conditions. (Kothari, 2004)
- Control (a.k.a. controlling) variables have no effect on other variables and are often kept the same throughout an experiment to prevent bias; while composite variables are often made up of two or more variables that are highly related to one another conceptually or statistically. (Indeed Editorial Team, 2021).
- Table 5 describes both control variables and composite variables, while providing an example of each.

Table 5. Controlling vs composite variables (Indeed Editorial Team, 2021).

	Control variables	Composite variables
Definition	Characteristics that are constant and do not change during a study	Two or more variables combined to make a more complex variable
Example	In an experiment about plant development, control variables might include the amounts of fertilizer and water each plant gets. These amounts are always the same so that they do not affect the plants' growth.	Overall health is an example of a composite variable if a researcher uses other variables, such as genetics, medical care, education, quality of environment and chosen behaviors, to determine overall health in an experiment.

5.2 Research & Statistical variables (cont'd)

- **Research hypothesis**: A research hypothesis is a specific, clear, and testable proposition or predictive statement about the possible outcome of a scientific research study based on a particular property of a population, such as presumed differences between groups on a particular variable or relationships between variables. (Lavrakas, 2011). The research hypothesis is a predictive statement that relates an independent variable to a dependent variable. Usually a research hypothesis must contain, at least, one independent and one dependent variable. Predictive statements which are not to be objectively verified or the relationships that are assumed but not to be tested, are not termed research hypotheses. (Kothari, 2004)
- **Experimental and non-experimental hypothesis-testing research:** When the purpose of research is to test a research hypothesis, it is termed as hypothesis-testing research. It can be of the experimental design or of the non-experimental design. Research in which the independent variable is manipulated is termed 'experimental hypothesis-testing research' and a research in which an independent variable is not manipulated is called 'non-experimental hypothesis-testing research'. (Kothari, 2004).

5.2 Research & Statistical variables (cont'd)

- **Experimental and control groups:** In an experimental hypothesis-testing research when a group is exposed to usual conditions, it is termed a 'control group', but when the group is exposed to some novel or special condition, it is termed an 'experimental group'. (Kothari, 2004)
- **Treatments:** The different conditions under which experimental and control groups are put are usually referred to as 'treatments'. (Kothari, 2004)
- **Experiment:** The process of examining the truth of a statistical hypothesis, relating to some research problem, is known as an experiment. (Kothari, 2004)
- **Experimental unit(s):** The pre-determined plots or the blocks, where different treatments are used, are known as experimental units. (Kothari, 2004)

Part 6

Research designs

6.1 Introduction

- Research design types has been the topic of contention in terms of literature over the years. Different authors have used so many different classifications over the years and there is no clear cut agreement on how to classify the different research design types.
- (Bouchrika, 2022) describes four approaches namely descriptive, experimental, correlational, and explanatory.
- Kothari (2004) describes two broad approaches namely exploratory/ formulative and descriptive/diagnostic.
- Between these two sources all types of research design under whichever names are amply explained. As an investigator it is important to understand which type of research design to use in your investigation. These approaches are described in this section.

6.2 Descriptive research

(Bouchrika, 2022) describes this type of research as follows:"

- In studies where the researcher is interested in describing a case, situation, or phenomenon, they are acting under a descriptive research design. As a theory-based design, it is interested in answering the how, what, when, and where questions, instead of the why. Descriptive research directs the researcher to understand the research problem before investigating why it even happens in the first place.
- Descriptive design furnishes the researcher with an opportunity to gain insight into the problem itself. It also helps the research team to see the need for the research. If it is not as clear or as necessary, exploratory research (which, according to Blaikie (2000), is considered as the first phase of research) may be needed. Descriptive research attempts to build on the groundwork made by exploration, such as providing additional information, filling in gaps in knowledge, or expanding it. Unique to descriptive research is that it also aims to collect as much data and information as possible.
- An example of descriptive research is market research. An investor, for example, may need to look at the market, such as its current state, its trends, and so on. Descriptive research can answer all these questions for the investor, which is why market research is an investment in itself,..."

6.3 Experimental research

(Bouchrika, 2022) describes this type of research as follows:"

- Using an experiment, the research attempts to establish a cause-and-effect relationship in a situation or phenomenon. It is a causal research design type where the researcher tries to observe the impact of a variable on a dependent one. In doing so, the researcher attempts to determine or predict what may occur based on experimental models (Anastas, 1999).
- Experimental research is a practical route to take, as it allows the researcher to find exactly what is working and what is not, and account for these changes accordingly to solve the research problem. Experiments are often used in the social sciences and in the medical field by grouping people, such as by using a control group as an independent variable."

6.4 Correlational research

(Bouchrika, 2022) describes this type of research as follows:"

- Like experimental research, correlational research aims to establish a relationship between two variables. The difference is that while experimental research tries to monitor changes between variables (causal), correlational research tries to look for associations and similarities between them (Sassower, 2017).
- As a non-experimental technique, it instead relies on evaluating the relationship between these variables using statistical analysis. To calculate the amount of correlation between two variables, a statistical method called Pearson's correlation coefficient is used (Mukaka, 2012), which is a value between -1 and +1. The more it leans toward a positive value, there is indeed a relationship between the two. A negative value denotes the variables are related but indirectly proportional, and zero denotes no relationship."

6.5 Explanatory research

(Bouchrika, 2022) describes this type of research as follows:"

- As evidenced by the name, explanatory research aims to explain the researcher's findings and ideas to expand the theory. Using this research design, the researchers explore the limits and boundaries of a subject in order to present the reader with the results that answer the what, how, and why of the research's central thesis. When conducting the research, the researcher should leave all biases behind and adapt to new data and/or findings.
- Researchers and students conduct explanatory research to find the underlying problem or a new angle to a problem. These may not always be readily apparent when initially proposing the research or it was not studied in-depth before (GradesFixer, 2019).
- Note that explanatory research does not seek to provide conclusive answers, but to give an avenue to researchers to plumb the depths of the subject."

6.6 Exploratory/formulative vs descriptive/diagnostic

- Table 6 summarizes the differences between these types of research design as described by Kothari (2004).

Table 6. Exploratory/ formulative vs descriptive/diagnostic (Kothari, 2004)

Research Design	*Type of study*	
	Exploratory of Formulative	*Descriptive/Diagnostic*
Overall design	Flexible design (design must provide opportunity for considering different aspects of the problem)	Rigid design (design must make enough provision for protection against bias and must maximise reliability)
(i) Sampling design	Non-probability sampling design (purposive or judgement sampling)	Probability sampling design (random sampling)
(ii) Statistical design	No pre-planned design for analysis	Pre-planned design for analysis
(iii) Observational design	Unstructured instruments for collection of data	Structured or well thought out instruments for collection of data
(iv) Operational design	No fixed decisions about the operational procedures	Advanced decisions about operational procedures.

Part 7

Principles of experimental design

The 3 R's

- The basic principles of experimental design were described by Fisher are randomization, replication and reduce noise (by controls). The description of these three are available in several literature. However, in this lesson we introduce them using a simplified explanation by Idrees (2014):"
- **Randomization.** The first principle of an experimental design is randomization, which is a random process of assigning treatments to the experimental units. The random process implies that every possible allotment of treatments has the same probability. An experimental unit is the smallest division of the experimental material, and a treatment means an experimental condition whose effect is to be measured and compared. The purpose of randomization is to remove bias and other sources of extraneous variation which are not controllable. Another advantage of randomization (accompanied by replication) is that it forms the basis of any valid statistical test. Hence, the treatments must be assigned at random to the experimental units. Randomization is usually done by drawing numbered cards from a well-shuffled pack of cards, by drawing numbered balls from a well-shaken container or by using tables of random numbers.

  Read more: https://www.emathzone.com/tutorials/basic-statistics/basic-principles-of-experimental-designs.html#ixzz7yOZqEPlC

The 3 R's

- **Replication.** The second principle of an experimental design is replication, which is a repetition of the basic experiment. In other words, it is a complete run for all the treatments to be tested in the experiment. In all experiments, some kind of variation is introduced because of the fact that the experimental units such as individuals or plots of land in agricultural experiments cannot be physically identical. This type of variation can be removed by using a number of experimental units. We therefore perform the experiment more than once, i.e., we repeat the basic experiment. An individual repetition is called a replicate. The number, the shape and the size of replicates depend upon the nature of the experimental material. A replication is used to:
  - i) Secure a more accurate estimate of the experimental error, a term which represents the differences that would be observed if the same treatments were applied several times to the same experimental units;
  - (ii) Decrease the experimental error and thereby increase precision, which is a measure of the variability of the experimental error; and
  - (iii) Obtain a more precise estimate of the mean effect of a treatment

Read more: https://www.emathzone.com/tutorials/basic-statistics/basic-principles-of-experimental-designs.html#ixzz7yOaVFOmO

The 3 R's

- **Local Control.** It has been observed that all extraneous sources of variation are not removed by randomization and replication. This necessitates a refinement of the experimental technique. In other words, we need to choose a design in such a manner that all extraneous sources of variation are brought under control. For this purpose, we make use of local control, a term referring to the amount of balancing, blocking and grouping of the experimental units. Balancing means that the treatments should he assigned to the experimental units in such a way that the result is a balanced arrangement of the treatments. Blocking means that like experimental units should be collected together to form a relatively homogeneous group. A block is also a replicate. The main purpose of the principle of local control is to increase the efficiency of an experimental design by decreasing the experimental error. The point to remember here is that the term local control should not be confused with the word control. The word control in experimental design is used for a treatment which does not receive any treatment when we need to find out the effectiveness of other treatments through comparison.

  Read more: https://www.emathzone.com/tutorials/basic-statistics/basic-principles-of-experimental-designs.html#ixzz7yObCmksu

Completely Randomized Design (CRD)

- The student is invited to read more on this type of design from available literature online.
- "A completely randomized design (CRD) is one where the treatments are assigned completely at random so that each experimental unit has the same chance of receiving any one treatment. For the CRD, any difference among experimental units receiving the same treatment is considered as experimental error. Hence, CRD is appropriate only for experiments with homogeneous experimental units, such as laboratory experiments, where environmental effects are relatively easy to control. For field experiments, where there is generally large variation among experimental plots in such environmental factors as soil, the CRD is rarely used." More details together with an example can be found at https://www.fao.org/3/x6831e/x6831e07.htm#:~:text=Almost%20all%20experiments%20involve%20the,randomization%2C%20replication%20and%20local%20control. , where the quoted text is drawn from.

Summary

- Research design is a framework that includes the methods and procedures to collect, analyze, and interpret data. In other words, the research design describes how the researcher will investigate the central problem of the research.
- Based on the design decisions the overall research design can be split into three components/parts: sampling design, observational design, and operational design.
- Research design can be viewed or described as being one of two perspectives: quantitative or qualitative
- Characteristics of good research design are neutrality, reliability, validity and generalization.
- Variables may be categorical, ordinal or nominal.
- In research variables may be dependent, independent, intervening, moderator, confounded, composite or extraneous.
- Research design approaches may be described as descriptive, experimental, correlational, and explanatory; other literature categorize the approaches as exploratory/formulative and descriptive/diagnostic.
- The 3 R's of experimental design are randomization, replication and noise reduction (local control).

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