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# SINGLE-SUBJECT RESEARCH METHOD: THE NEEDED SIMPLIFICATION

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**ABSTRACT:** *Research, the scientific quest for knowledge discovery and dissemination, is done in accordance with specific research methods. Using documental analysis research method and a randomly drawn sample of 1557 from a population of 46,376 lecturers, results showed that single-subject research is the least adopted method in Nigeria; probably because it has the greatest dearth of readily available information. Single-subject research method is however very appropriate for establishment of cause-and-effect relationships between variables. It is a special experimental methodological approach for investigation of the effects of intervention measures on an individual's clinical behavior; using the very subject as his own control by changing the intervention treatment conditions presented to him and carefully assessing via repeated measurements, the impact of the changes on the subject as he exhibits certain new behavior a number of times. This paper has provided elaborate information on five single-subject designs (A→B→A→B, multiple-baseline, interaction, alternating-treatment, and changing-criterion); and four single-subject data analysis techniques (visual analysis, therapeutic criterion study, interrupted time-series statistics, and statistical analysis) to fill the existing knowledge gap.*

**KEYWORDS:** *Research methods; Single-subject research; Cause-and-effect relationships; Single-subject designs; Single-subject data analysis techniques; A→B→A→B design; Multiple base-line design; Interaction design; Alternating-treatment design; Changing-criterion design; Documental analysis.*

## INTRODUCTION

Research can satisfactorily be defined as the logical, systematic and objective collection, analysis, synthesis, evaluation and recording of accurate and controlled observations for the development of generalizations, principles, or theories that are ultimately aimed at description, explanation, prediction and control of natural phenomena to meet specific needs of man (Kpolovie, 2010, 3). Eight characteristics of research (Kpolovie, 2016) captured in this definition are that research is:

1. Goal oriented, aimed at meeting man's needs
2. Concerned with objective and controlled observations
3. Statistical
4. Scientific
5. About theory development and verification
6. About correct description, explanation, prediction, and control of future occurrence
7. Accurate recording and reporting
8. Executed only by the self-disciplined, curious, persistent, and objectively minded.

There are several methods that can be adopted in execution of research; and they are collectively referred to as research methods (Kpolovie, 2016; 2010; Panneerselvam, 2014;



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Kothari & Garg, 2015; Rozakis, 2004; Keeves, 1990; Anderman, 2009). This investigation was primarily aimed at finding out the research method that is least adopted by lecturers in Nigeria in order to provide grandiose information on that research method. Research methods essentially include:

- Action research
- Correlational research
- Documental analysis research
- Ethnographic research
- Evaluation research
- Ex post facto research
- Experimental research
- Historical research
- Instrumentation research
- Quasi-experimental research
- Single-subject research
- Survey research
- Triangulation research

What each of these research methods (ways of execution research) means or entails, according to Kpolovie (2016; 2010), is aptly summarized in a tabular form in **Table 1**.

**Table 1: List of research methods**

| S/No | Research Method | Denotation |
|---|---|---|
| 1 | Action research method | A collaborative, situational and realistic small-scale intervention in an ongoing program for immediate diagnosis and instant resolution of problems in the implementation process through formulation and testing of suitable hypotheses for improvement of the practitioners' praxis to improve organizational goal attainment. |
| 2 | Correlational research method | Adopted for investigation of the magnitude and direction of relationship that exists between a criterion variable and one or more predictor variables. |
| 3 | Documental analysis research method | Allows for gathering of both secondary and primary data qualitatively and quantitatively from hardcopies and softcopies of existing publications via the World Wide Web through internal and external criticisms for authenticity, accuracy, validity and reliability of the data source. |
| 4 | Ethnographic research method | A naturalistic anthropological inquiry that employs continual ongoing in-depth participant observations and interviews of, and conversations and interactions with the subjects for valid reliable and dependable description of the dynamic everyday cultural characteristics, experiences and practices of individuals in a particular society, group, organization, institution or situation. |
| 5 | Evaluation research method | Executed for passing of value judgments on the basis of standard goals or objectives set, actual implementation of entire human and physical resources of a particular program |


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| | | |
|---|---|---|
| | | and the results yielded by the program within a given time frame. |
| 6 | Ex post facto research method | Is used to cover investigations that are done retrospectively (after the effect has occurred) to identify probable cause-and-effect relations between the variables under study through observation of existing conditions and inquisitively searching back historically for the plausible causal factors. |
| 7 | Experimental research method | The best research methodology for investigation of cause-and-effect relationships between independent and dependent variables. |
| 8 | Historical research method | A logical, systematic, critical and objective collection, analysis, synthesis and evaluation of meaningful chronological human activities and achievements in the past for a dependable integrated account that aids both in the understanding and reconstruction of the present for greater accomplishments in the future. |
| 9 | Instrumentation research method | Deals with the psychometric principles for and the actual test development, validation (establishment of validity and reliability), standardization (provision of standard instructions and norm or criterion) on the basis of certain test theories like Classical Test Theory, and Item Response Theory, as well as scaling methods, elimination of biases in testing, and writing of suitable detailed test manual. |
| 10 | Quasi-experimental research method | Used to approximate conditions of true experiment in situations that do not permit the control and manipulation of all relevant variables. An example of such conditions is when total randomization cannot be applied to control all known and unknown extraneous variables required for true experimentation. |
| 11 | Single-subject research method | Uses the very subject as his own control by changing the intervention treatment presented to him and carefully assessing via repeated observations or measurements, the impact of the changes in the experimental treatment on the subject as he exhibits certain new behavior a number of times under the various treatment conditions. |
| 12 | Survey research method | A developmental field investigation that systematically collects, analyzes and synthesizes quantitative data on a large representative sample of a given population to cross-sectionally or longitudinally identify, describe and explain the relative incidence, distribution and interrelations of political, educational, psychological, sociological, commercial or economic and clinical variables, as well as other characteristics about the sample through data obtained from personal interview, telephone interview, self-administered inquiry and computer-assisted inquiry for accurate generalization to cover the entire population. |
| 13 | Triangulation research method | Uses multiple research methodologies, measurement instruments and statistical tools that are related to the |


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| | | |
|---|---|---|
| | | theoretical construct of interest to more comprehensively investigate one particular phenomenon to overcome the inherent weakness of a single design and measurement instrument. |

As will soon be seen under results, single-subject research method is the least adopted method in Nigeria. Single-subject research deals with experimentation with one subject by subjecting him to detailed examinations for conclusive utilitarian evaluation and determination of the effects of the experimental treatment conditions on him (Kpolovie, 2016; Kpolovie, & Ololube, 2013; Cohen & Manion, 1989; Cohen, Manion, & Morrison, 2008). In this way, single-subject research is successfully used to investigate pure cause (remediation intervention) and effect (new behavioral change) relationships in a manner that excludes possibility of rival hypotheses even though randomization and inclusion of a control group were not evoked in the situation (Shultz, Whitney & Zickar, 2014; Ololube, & Kpolovie, 2012).

Single-subject research adopts the core features or characteristics of time-series design which are repeated measurements or observations before, during and after administration of the experimental treatment(s) on a single subject to reach basic causal relation (Kothari & Garg, 2015; Crowl, 1996). The series of measurements or observations before the treatment collectively serve as predictor of the subject's behavior after the treatment, assuming no treatment was given (Rozakis, 2004). If the subject's behavior denoted by several post-treatment observations or measurements significantly differs from the predicted order as indicated by the multiple pretreatment observations, then the experimental treatment is said to have had remarkable effect on the subject (Ololube, Kpolovie, & Makewa, 2015).

Aptly, a single-subject research design must possess at least five indispensable phases, conditions, characteristics or elements, namely (Kpolovie, 2016; 2010):

i. Multiple measurements of the subject with respect to the dependent variable under investigation before introduction of treatment. This can be termed $A^1$ baseline.

ii. Administration of the experimental treatment conditions (the independent variable) to the subject for a period of time and multiple measurements are taken within this period to reflect the effect of the treatment. This constitutes $B^1$ treatment condition.

iii. Multiple measurements of the subject in terms of the dependent variable of interest after administration of the treatment. At this period, the treatment condition ($B^1$) has been completely removed and measurements are taken. With the total withdrawal of $B^1$, the situation reverts back to statuesque, that is, its original baseline. This phase is called $A^2$ baseline.

iv. In the fourth phase, the same experimental treatment condition that was given in phase two (i.e. the $B^1$) is re-administered to the subject for the same length of time, while multiple measurements are simultaneously obtained. This phase can be referred to as $B^2$ treatment condition.

v. At the fifth phase, comparisons of the subject's behavior or performance during $A^1$, $B^1$, $A^2$ and $B^2$ are made; and graphically represented with level or slope lines that depict the various measures under the four conditions. If performance or behaviors during baselines $A^1$ and $A^2$ are similar but greatly different from behaviors during treatments $B^1$ and $B^2$, then the effect of the independent variable (treatment) on the dependent variable (behaviors) has been ascertained.


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The choice of single-subject research is dependent on the purpose of the investigation, the scenarios or circumstances under which the study is to be executed and the population that generalizations of the findings are to cover (Panneerselvam, 2014; Graziano & Raulin, 2007). For instance, behavior modification investigations and studies for remediation of an individual's already diagnosed cognitive, affective and/or psychomotor problems demand the use of single-subject research (Ololube, Kpolovie, & Makewa, 2015). Using Nigeria as a single-subject in-depth study of MOOCs as an educational intervention; Kpolovie and Iderima (2016) found absence of any platform for delivery of cMOOCs in Nigeria, and that it is only at postgraduate level that readiness for xMOOCs does exists in the country. Earlier, Kpolovie and Obilor (2013) and Kpolovie, Obilor and Ololube (2015) had found that the National Open University of Nigeria as an intervention to ensure higher education for all in Nigeria was rather a paradox in policy practice.

The study reported in this article aimed at and very successfully:

1. Identified the least adopted research method in Nigeria
2. Delineated single-subject research
3. Illustratively discussed five single-subject designs vividly
4. Lucidly explicated four approaches for analyzing single-subject research data.

## METHODOLOGY

Documental analysis research design that guarantees authenticity and accuracy to ascertain information on single-subject research was adopted. Documental analysis in the 21st century, is a research design that allows for gathering of both secondary and primary data qualitatively and quantitatively from hardcopies and softcopies of existing publications via the World Wide Web through internal and external criticisms for authenticity, accuracy, validity and reliability of the data source (Kpolovie & Obilor, 2013a; Kpolovie, 2010). Documentary analysis deals with literature and text material analysis which constitute an integral part of data gathering instruments as they are valuable sources of data gathering in qualitative research. The literature and text materials include both secondary and primary sources. While reports and publications that have first-hand information on the theme of this paper are the primary sources; information from textbooks, journals, quoted materials, and reports of investigations done by other researchers that are relevant to the theme of this study constitute the secondary source. Each source of information gathering was subjected to external and internal criticisms to ascertain authenticity of data as well as accuracy of data.

Research works could be classified in a number of ways. One of such classifications categorises research works broadly into quantitative research and qualitative research. This article is a position paper in the category of qualitative research. Qualitative research allows for best simplification and understanding of the problem under investigation. It has given the current researcher room to source for and provide detailed information on single-subject research which is the least adopted research method by the faculty in Nigerian universities. The reach information that this study provides is aimed at overcoming the factor of dearth of readily available literature that was majorly indicated as responsible factor for the rare adoption of single-subject research method.

The population of this study is the 46,880 teaching staff (37,504 from Federal, and 9,376 from privately owned universities in Nigeria) (NEEDS Assessment of Nigerian Universities

Committee, 2013; FRN National Population Commission, 2014; Federal Ministry of Education, 2014). With the aid of Table of Random Numbers, a sample of 1557 faculty was randomly drawn for this investigation. SPSS Version 22 Graphic or pictorial illustrations were used for results presentation.

## RESULTS AND DISCUSSION

It can be discerned from **Table 2** that 778 (7.8%) of the respondents have employed experimental research method in carrying out research. While as much as 1305 (13.1%) of Nigerian university lecturers have applied quasi-experimental research method in executing research, only a very significantly low number, 62 (0.6%) of the lecturers have made use of single-subject research method in doing research. The main reason advanced by great majority of the staff for none adoption of single-subject research method in investigations is dearth of information on the research method. This indicates urgent and immediate need for provision of self-explanatory information on how single-subject research can suitably be adopted in research execution in Nigeria. A thorough account of single-subject research method is consequently provided in this paper.

The **Table 2** has further revealed that 1480 (14.9) of the lecturers have employed correlational research method in their studies. Evaluation research; action research; and ex post facto research have respectively been adopted by 427 (4.3%); 665 (6.7%); and 1488 (14.9%) of teaching staff in Nigerian universities. Triangulation research; historical; research; ethnographic research; and survey research methods have been adopted by 535 (5.4%); 674 (6.8%); 422 (4.6%); and 1332 (13.4%), respectively of university teachers in Nigeria in their investigations. While instrumentation research has been applied by 461 (4.6%) lecturers, 305 (3.1%) of the respondents have made use of documental analysis research method in their studies.

**Table 2: Percentage of lecturers who have used a given research method in Nigeria**

**ResMethods**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | Experimental research | 778 | 7.8 | 7.8 | 7.8 |
| | Quasi-experimental research | 1305 | 13.1 | 13.1 | 21.0 |
| | Single-subject research | 62 | .6 | .6 | 21.6 |
| | Correlational research | 1480 | 14.9 | 14.9 | 36.5 |
| | Evaluation research | 427 | 4.3 | 4.3 | 40.8 |
| | Action research | 665 | 6.7 | 6.7 | 47.5 |
| | Ex post facto research | 1488 | 14.9 | 15.0 | 62.5 |
| | Triangulation research | 535 | 5.4 | 5.4 | 67.8 |
| | Historical research | 674 | 6.8 | 6.8 | 74.6 |
| | Ethnographic research | 422 | 4.2 | 4.2 | 78.9 |
| | Survey research | 1332 | 13.4 | 13.4 | 92.3 |


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| | | | | | |
|---|---|---|---|---|---|
| | Instrumentation research | 461 | 4.6 | 4.6 | 96.9 |
| | Documental analysis research | 305 | 3.1 | 3.1 | 100.0 |
| | Total | 9934 | 99.7 | 100.0 | |
| Missing | System | 32 | .3 | | |
| Total | | 9966 | 100.0 | | |

The SPSS Version 22 used for data analysis of this investigation has equally presented two graphic representations, Pie Chart in **Figure 1** and Bar Chart in **Figure 2**, of the frequency with which teaching staff of universities in Nigeria have used each of the listed 13 research methods in executing research. The Pie chart and Bar chat have pictorially shown the frequency of Nigerian lecturers' use of experimental research; quasi-experimental; single-subject; correlational research methods to be 778; 1305; 62; and 1480, respectively. While evaluation research and action research have 427 and 665 frequency of use respectively, ex post facto research have a frequency of 1488. Triangulation research has 535 frequency; historical research has 674 frequency of use; and ethnographic research has 422 frequency of application. Survey has been adopted by 1332 lecturers, instrumentation research and documental analysis research respectively have 461 and 305 usage by the teaching staff.

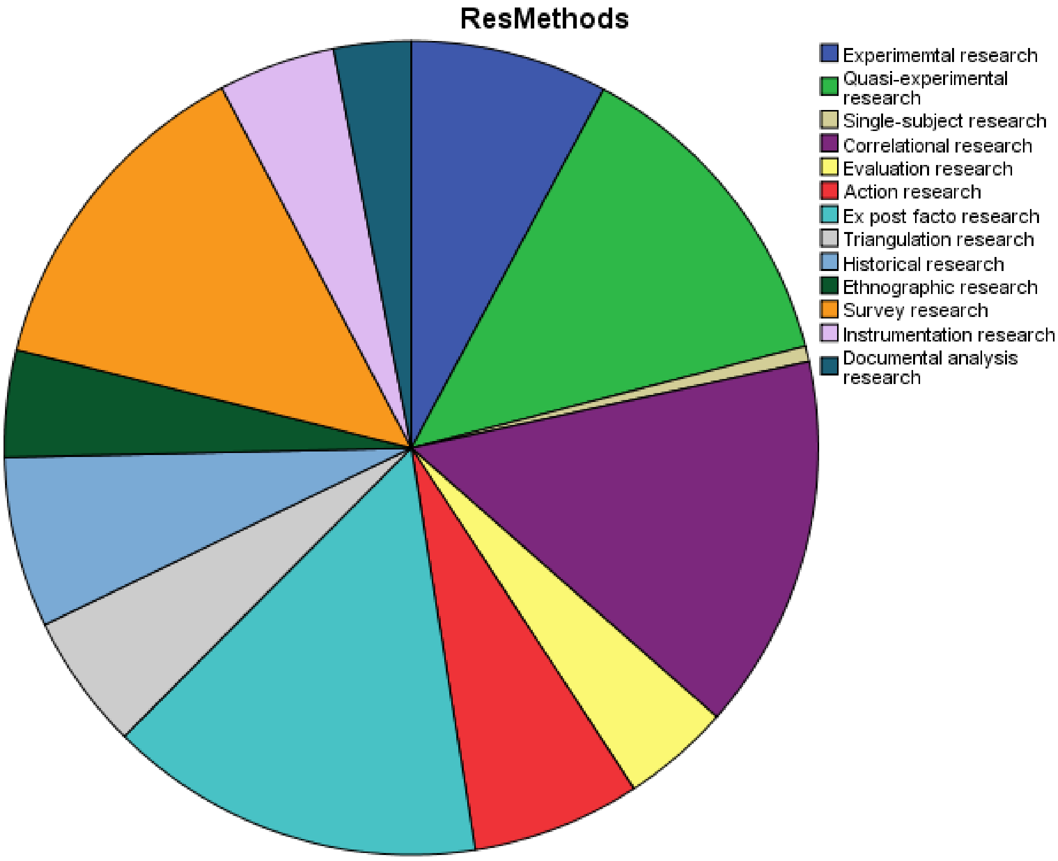


**Figure 1: Pie chart indicating frequency of research methods usage by lecturers in Nigeria**


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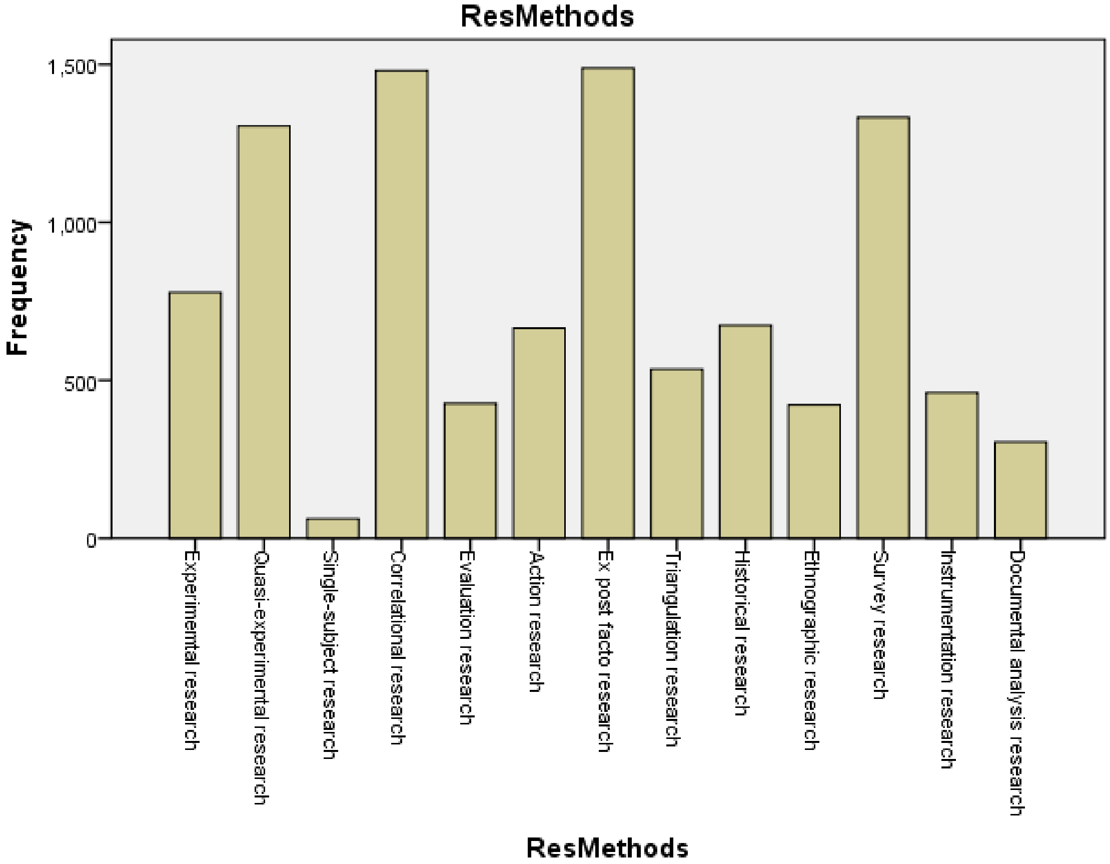


**Figure 2: Bar chart of number of lecturers who have used a given research method in Nigeria**

The Pie chart (**Figure 1**) and particularly Bar chart (**Figure 2**) have very clearly shown that apart from single-subject research method that has virtually not been used by Nigerian researchers in their studies, each of the other 12 research method have been adopted by a great deal of lecturers in the country to carry out research. As mentioned earlier, dearth of readily available information is the recurring reason advanced by the lecturers for the very rare use of single-subject research in execution of investigations. The existing lacuna of relevant information on single-subject research method is therefore profusely presented in this study to very lucidly and vividly cover five distinct single-subject research designs and four statistical approaches for analysis of single-subject research data.

## Single-Subject Research Designs

There are five distinct, and mutually exclusive, designs of single-subject research that outlined and exhaustively discussed herein. They are:

- A→B→A→B design,
- Multiple-baseline design,
- Interaction design,
- Alternating-treatment design, and
- Changing-criterion design.


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**A→B→A→B Single-Subject Design**

The A→B→A→B design is used for data collection about a particular behavior of the same subject, operating as his own control, under four phases, stages or conditions that are described simply as A→B→A→B to unambiguously generate pure causal effect evidence or relationship between an independent variable and a dependent variable. The first condition or stage (A) is the baseline period. Baseline refers to the natural value or level of a variable in its original state when it is not affected by any special or unusual influences. Baseline is also seen as the average number of times an event or behavior naturally occurs within a given period of time as Myers (1987: 373) "a measure of the dependent variable as it occurs without the experimental manipulation, used to assess the impact of the experimental intervention." Kantowitz, Roediger III and Elmes (2005: 532) defined baseline as "a measurement used as the basis for comparison, usually when no treatment is given."

During the baseline period, the subject is severally assessed or observed with regard to the particular dependent variable or behavior that is under investigation. The number of observations required at this stage must be many enough to show that the subject's typical behavior has been reliably demonstrated or determined. The baseline period is a pretreatment condition that is of extreme importance in single-subject research because it is indeed the best estimate of what would have occurred without introduction or application of any experimental intervention (treatment condition). That is, the baseline condition can and should be seen as the target behavior as recorded in its freely occurring state to naturally typify the subject.

The multiple measurements taken at the baseline period clearly depict the particular behavior in its natural typicality under investigation in the manner that it truly is prior to presentation of the experimental treatment that is designed to alter (increase or decrease) the specific behavior. It is the baseline measurements that correctly serve as the frame of reference or yardstick against which the influence of any treatment condition on that behavior is judged (Best, 1981; Blaxter, Hughes, &Tight, 2009; Breakwell, Hammond, & Fife-Schaw, 2001). A minimum of five valid measurements should be taken of the dependent variable at the baseline phase for a very clear, reliable and dependable picture of the currently existing condition of the behavior that will serve as the criterion against which the effect of intervention or experimental treatment condition will be judged (Rugg & Petre, 2009).

The second stage is the presentation of the first B condition of the A→B→A→B design. This phase refers to exposure to the experimental treatment condition that is deliberately introduced and administered to the subject exclusively for the purpose of drastically changing or altering the behavior that has been observed, measured and recorded during the baseline period. The B is administered and maintained for long enough time (usually as long as the time the baseline period lasted) to enable the researcher obtain series of valid recorded observations or measurements that indicate stability of the behavior under this treatment condition. It is the substantially stable behavioral change observed at this stage that is attributable to the manipulation of the independent variable. That is, if each time a measurement of the dependent variable is taken at this phase, a marked increment is noticed, then taking of more and more measurements should continue while the treatment lasts until a point that additional measurements no longer indicate systematic sharp increase. Once stability of the extent to which the subject exhibits the behavior that constitutes the dependent variable is reached, this phase is said to have been completed and considered as such.



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At this level, the investigator cannot unquestionably conclude that the difference in behavior between the baseline observations (the first A period) and the measurements obtained at the first B period (treatment condition) is caused purely by the administration of the treatment. This is because some other variables could have possibly been the cause of the difference or the improvement in behavior. Perhaps, the change could have even occurred naturally without any treatment at all. It is as a result of the possibility of rival interpretations and hypotheses at this level that the design has two more phases that will collectively rule out all possibilities of extraneous causal factors and unquestionably establish causal relationship between the independent and dependent variables.

The third stage of the A→B→A→B design is the deliberate recurrence of A (the second A) or baseline condition to ascertain whether the behavioural change gained with the introduction of treatment at phase B will be sustained or not without continuation of the treatment. The second appearance of baseline conditions in the design is deliberate because the researcher intentionally withdraws the entire experimental treatment condition and simultaneously reinstates the baseline conditions as a crucial step in verification of the causality potency of the independent variable. This is because, if the improved behavior of the subject at B phase reverts back to the original low level at the initial pretreatment phase, then a strong evidence of the effectiveness of the intervention treatment has been established. In this way, the likelihood that a variable other than the experimental one influenced the dependent variable only during the period that treatment was being administered and not before or after the treatment session, has been drastically reduced, if not entirely removed (Ary, Jacobs, & Razavieh, 2002; James & Gilliland, 2005). Therefore, whenever elimination of phase B treatment in an A→B→A→B design causes reversal of behavior back to its pretreatment level, or baseline condition; an acceptable demonstration that the experimental treatment condition, and nothing else, produced the behavioural change observed during the B stage of the investigation has been proved. Such behavioural reversal is a crucial necessity for causal influence to be made in single-subject design; because without it, cause-and-effect relationship cannot be proved in the design (Hoban, 2002; Bernal, 1987).

The last stage in the A→B→A→B single-subject design is the resurgence of B (the second B) in which the eliminated experimental treatment condition or intervention is reinstated or reintroduced for determination of whether it will again be accompanied with remarkable steady improvement in behavior to stability as it did during the first exposure to the treatment condition. The re-administration of the experimental treatment is of critical importance in the design. The reason for this is not farfetched. With it, the sharp rise or improvement in the subject’s behavior is observed twice with several measurements at each of the B conditions, which is against the two sets of measurements during A conditions when the subject’s behavior was at the baseline level (pretreatment time). With the poor behavior of the subject at the two baseline conditions and highly improved behavior of the same subject during the two experimental treatment conditions, absolute cause-and-effect relationship between the independent and dependent variables is proved beyond every reasonable doubts as possibilities of rival hypotheses are ruled out completely (Ololube, Nwokolo, Onyekwere, & Kpolovie, 2013). Diagrammatical illustration of A→B→A→B design is presented in Figure 3.

**Limitations of A→B→A→B design**

It must however be pointed out that the A→B→A→B single-subject research design has some shortcomings; the greatest of which is refusal or failure of certain behavior to reverse back to


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the baseline level after exposure to the experimental treatment. This scenario occurs when learning has fully taken place in the subject with respect to the behavior under investigation. Recall that learning is defined as a relatively permanent change in behavior of an organism (Kpolovie, 2012). It is also known that any new behavior or information that the subject successfully transfers from his sensory memory through his short-term memory to his long-term memory remains permanently in him, often irrespective of withdrawal of reinforcement. If the improvement in the behavior of the subject during the experimental treatment has been fully learned or transferred into his long-term memory, even when the treatment condition is withdrawn during the second A period, the subject's improved behavior remains permanently so, without reversing back to the original baseline level (Kpolovie, 2012; Jackson, 2006). Such refusal of behavior to revert back to the pretreatment condition could also be caused by carry-over effect of the treatment. Except there is reversal of behavior back to the original baseline, the researcher or experimenter cannot be certain that the change for better in the subject's behavior was caused by the exposure to the experimental treatment condition alone, and not by any combination of extraneous variables (Marquardt, 2009).

**Example of investigation done with A→B→A→B design**

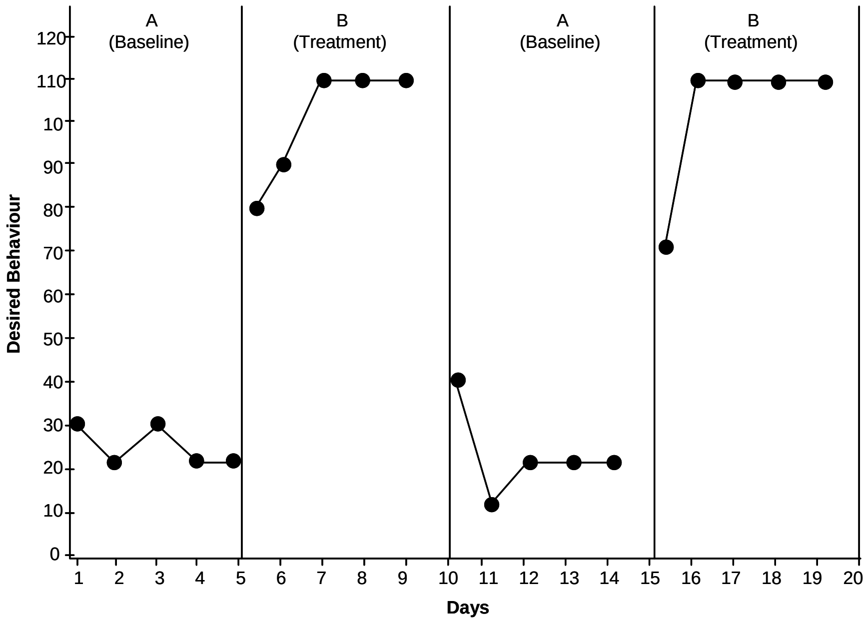


**Figure 3: Use of A→B→A→B design for improvement of Chief James Kpolovie's reading behavior.**

The **Figure 3** indicates twenty (20) observations that the current researcher took of his father's (Chief James Kpolovie) reading behavior. Due to advancement in age, Chief James Kpolovie got the problem of short-sightedness which made it very difficult for him to clearly see and read materials printed with 12 font size. The author took him to University of Port Harcourt Teaching Hospital, where he obtained a pair of medicated eyeglasses. On getting home, the author took these observations. Chief James was given five different pages of newspapers to read aloud without wearing the eyeglasses, while his achievements in the reading task were recorded. These constituted the first A (baseline) information in **Figure 3**. Thereafter, he was asked to wear the eyeglasses and read the same five pages of the newspapers. His performance


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accelerated drastically, and were recorded and represented in the first B (intervention treatment) section of **Figure 3**. Later, he was made to read the same materials without wearing his newly acquired pair of eyeglasses, and his successes were recorded and presented in the second A (baseline) section of the figure. Finally, Chief James was made to read the same materials with his eyeglasses on. His performance again improved tremendously to the first treatment level. These are represented in the second B (treatment) section of the **Figure 3**. The researcher concluded that his elderly father's tremendous improvement in reading of materials printed with 10, 9, and 8 font sizes as contained in the newspapers pages used in this experiment was caused solely by the wearing of the medicated eyeglasses, and nothing else. In this way, the effectiveness of the newly acquired eyeglasses was demonstrated beyond all possible doubts at home.

**Multiple-Baseline Design**

Multiple-baseline design demonstrates the experimental intervention or treatment effect on the dependent variable by using more than one baseline, with each of the baselines representing a different subject, behavior or setting. Usually, the second baseline is twice longer than the first baseline, the third baseline is thrice longer than the first baseline, and so on; that extends into the experimental treatment of the previous ones. For the experimental treatment or intervention to have causal effect on the dependent variable, each of the subjects for the different baselines will show remarkable improvement with regard to the dependent variable only after introduction of the experimental treatment condition. A true causal effect of treatment in multiple-baseline design is proved when the replicated subjects show the same pattern of behavioural improvement from the moment of exposure to the treatment for each of the subjects (Ololube, Kpolovie, & Makewa, 2015).

The experimenter using multiple-baseline design increases internal validity by controlling for history, maturation and some other threats to internal validity by extending each of the subsequent subjects' baseline measurements until after an experimental treatment effect has been demonstrated with the immediate prior subject (Lankshear & Knobel, 2011; Meltzoff, 2007). External validity is also ensured with multiple-baseline design as it allows for relatively more accurate generalizability of finding to other comparable or similar subjects through demonstration of the effect of treatment or intervention with more than one subject.

Multiple-baseline design is the most appropriate of single-subject research designs to be used in a situation that it is not possible or ethical for withdrawal of experimental intervention to cause return or reversal of behavior back to the pretreatment or baseline condition. It is also very suitable when greater internal validity of the experiment is required by overcoming carry-over effects, history and maturation that threatens validity; as well as when the findings are to be generalized to cover an acceptable population (Best & Kahn, 2007). This is largely because the effectiveness of multiple-baseline design does not depend on withdrawal or termination of treatment condition and its required accompanying extinction of behavioural gains recorded during the treatment (Smith, 1975; Silverman & Casazza, 2000).

In multiple-baseline design, the experimental intervention or treatment condition is successively administered to several subjects or to the same subject in several settings during and after establishment of baseline behaviors in each case. In other words, the experimental behavior in multiple-baseline design is administered to the target behavior for many subjects or situations successively after the determination and collection of baseline data in each situation. If the behavior exposed to the experimental intervention at a period in time changes


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and remains changed as the treatment continues indefinitely while all others (behaviors or subjects) remain at the baseline level until each receives the treatment and changes, then cause-and-effect relationship has been unambiguously established between the independent and dependent variables. This certainty is because only the exposure to experimental treatment in each case produces and maintains remarkable behavioral change for better; it becomes increasingly implausible for rival hypotheses to contemporaneously influence the target behavior at the same time as the treatment was administered (Kpolovie, Joe, & Okoto, 2014). It is on the strength of this principle that Fraenkel and Wallen (2003:312-313) concluded that:

> When using a multiple-baseline design across behaviors, the researcher systematically applies the treatment at different times for each behavior until all of them are undergoing the treatment. If behavior changes in each case only after the treatment has been applied, the treatment is (unquestionably) judged to be the cause of the change … In this design, treatment is applied first to change behavior 1, then behavior 2, and then behavior 3 until all three behaviors are undergoing the treatment.

A hypothetical diagram that illustrates an effective multiple-baseline design either with three different subjects for one behavior or three different behaviors for one subject is provided in Figure 4.

**Limitation of Multiple-Baseline Design**

The greatest of the short-comings of multiple-baseline design that must be mentioned for researchers wishing to use the design to necessarily prevent is that the design demands independence of behaviors that are under investigation. Multiple-baseline design that studies different behaviors for one subject demands that the behaviors should not be interdependent on or interrelated with one another. The reason for this requirement is that any such interdependence between or amongst the behaviors will automatically contaminate the results of the investigation as experimental treatment given to the first behavior will result in increase or improvement of that behavior and any other of the behaviors that is interrelated with the first behavior. For example, classroom behaviors of inappropriate motor skills, inappropriate tasks and inappropriate verbalizations are interrelated and any experimental treatment that affects one of them automatically affects the other two; and thus confounding outcome of the investigation. Therefore, before selecting this design, the researcher must carefully


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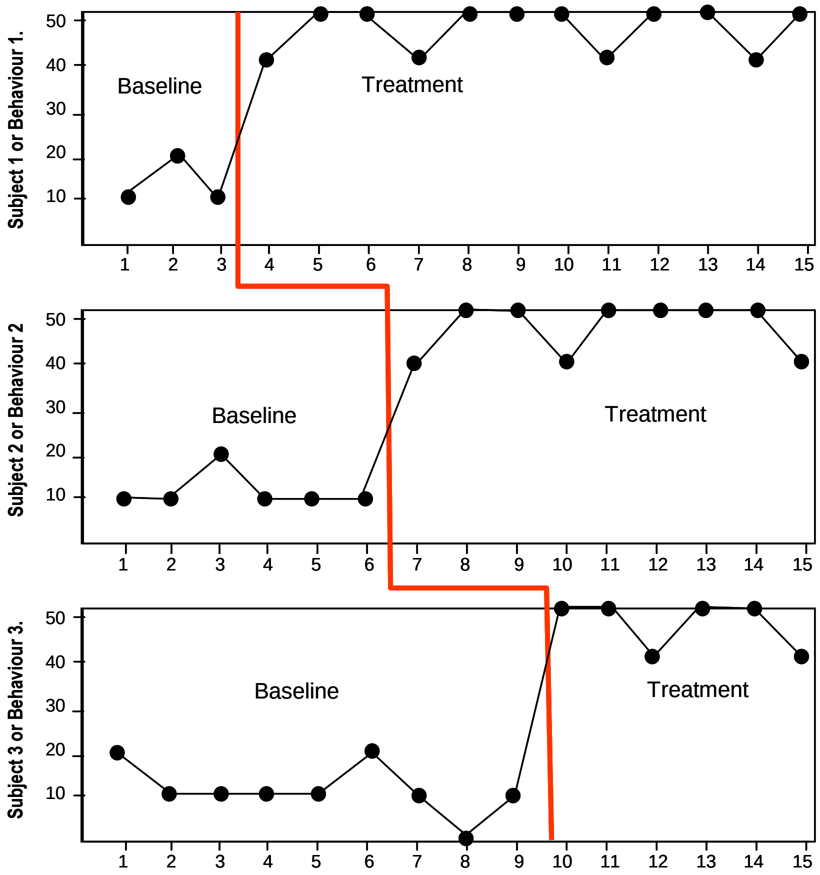


**Figure 4: Hypothetical multiple-baseline design results**

Consider the behaviors that he intends to investigate and be sure that they do not depend on one another. This is because when treatment is accorded to one behavior, it contemporaneously influences the other behaviors related to it as interdependence destroys the sensitivity and power of the investigation by making it impossible to ascertain what exactly that caused alteration or change in the behaviors that are yet to be exposed to the experimental intervention (Kpolovie, 2012). A possible way that this problem of interdependence of behaviors could be overcome by the researcher is by choosing only behaviors that are independent on one another. Unfortunately however, this cannot be known in advance without first collecting data and analyzing them on the behaviors to be sure that they are not interrelated. The most effective way of overcoming the problem is by using multiple-baseline design that investigates different subjects in terms of one behavior as explained in the first two paragraphs on multiple-baseline design (Kpolovie, Joe, & Okoto, 2014).

**Interaction Design**

Single-subject interaction design is the most valuable and most fascinating extension of the A→B→A→B design to incorporate in-depth study of the combined or interactive effect of two specific independent variables on the dependent variable. This, it does in strict compliance with one of the cardinal rules of single-subject research that only one variable can be allowed to vary from one phase of the research to another by investigating two subjects and two independent variables separately but contemporaneously to absolutely depict causal effect of each of the variables and the interactive effect of both variables in the two subjects via double baselines, triple two but single experimental treatments and double combined treatments in


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each of the cases (Briggs, Ololube, & Kpolovie, 2014). This design is clearly illustrated below with a hypothetical separate and combined effects of concrete reinforcement (token gift) and verbal reinforcement (praise) on persistence in solving mathematics problems among two senior secondary (SS I) students who ordinarily hate learning of mathematics.

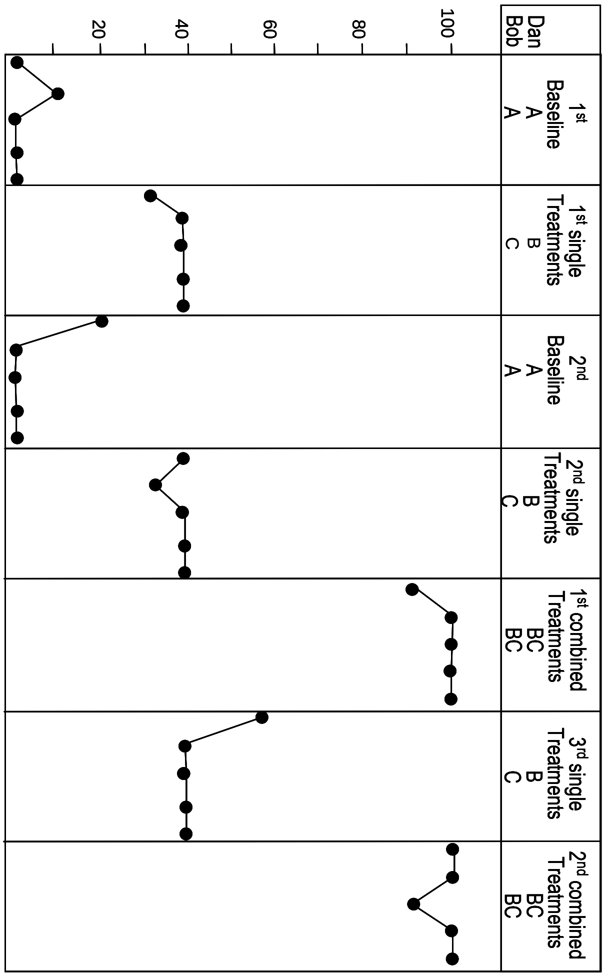


**Figure 5: Hypothetical single and combined effects of concrete (B) and verbal (C) reinforcements on Dan and Bob's persistence in solving mathematics.**

It is compulsory to make use of two subjects (Dan and Bob in this case) and two independent variables (concrete and verbal reinforcements) to investigate the separate effect of each of the independent variables and the interactive (combined) effect of the two variables on the one dependent variable (persistence in studying mathematics). The two subjects who are both SS 1 students have been found originally or typically to hate studying or learning mathematics. Their original state is depicted with the first baseline data for each of them. Next was the introduction of the first single treatments in which Dan was offered token gift (concrete reinforcement) for persisting in the learning of mathematics, and Bob was praised (verbal reinforcement) for doing the same thing. Because of the reinforcements, both subjects improved greatly in studying mathematics persistently as can be seen under the first single treatments column in **Figure 5**. Like A→B→A→B design, the experimental treatments were withdrawn to ensure a second baseline condition. Consequently, the subjects' persistence in studying mathematics dropped drastically to zero level as it was, typically. To confirm beyond every possible doubt that the former rise or increments in their persistence was caused by the treatment, the same treatment


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conditions were represented to the subjects. With this, the persistence in learning of quantitative or mathematics again increased. At this point, it is confirmed that the concrete reinforcement and verbal reinforcement were separately effective in improving the desired behavior. Up to this point or phase of the experiment, two A→B→A→B designs, one for Dan and the other for Bob, have been successfully executed.

For determination of the interaction effect, both concrete and verbal reinforcements were given to each of the subjects. Interestingly, this resulted in greater persistence in studying mathematics by both Dan and Bob as shown under 1st combined treatments BC. To rule out the possibility of every other rival hypotheses or explanations for the sudden dramatic rise in persistence from the moment when both B and C treatments were jointly given, the combined treatments were withdrawn such that Dan was left with only treatment B with its effect and Bob was left with only treatment C plus its accompanying effect as can be discerned under 3rd single treatments B for Dan and C for Bob. With this withdrawal, there was a reversal of behavior (persistence in studying mathematics) to the previous levels when the subjects were exposed to the first and second single treatments.

Finally, treatments B and C were combined once more and administered to the subjects. Again, both subjects' persistence in solving mathematics rose to the peak as it did when the combined treatments were first administered. This dramatic rise can be discerned from the second combined treatments BC for each of the two subjects in the last column of **Figure 5**. At this point it has been unambiguously proved that treatment B (token gift) and treatment C (praise) individually have causal effect on the dependent variable; and that the interaction or combined effect of the two treatments (B and C) on the dependent variable was even much greater. Therefore, for maximum persistence in the study of mathematics, subjects should be exposed to the combination of concrete and verbal reinforcements.

Although Dan and Bob's levels of persistency in learning of mathematics were equal when observations or measurements were taken at each of the seven phases of the experiment, concrete reinforcement can never be said to have influenced verbal reinforcement and vice versa because the two different types of experimental intervention conditions were taken separately by two different subjects independently. It only implies that either of the two experimental interventions (treatments) could be used to remedy the problem of poor or low persistence in the study of mathematics that some SS I students (particularly those in art class) have. For an aggressive remediation of the problem, both concrete and verbal reinforcements need to be combined and administered to have the interactive effect that dramatically supersedes individual administration of either of the two reinforcements (Briggs, Ololube, & Kpolovie, 2014).

Generally, isolation of the interactive effect of two independent variables from the effect that would be demonstrated by administration of only one of the independent variables on the dependent variable, analysis of the influence of each of the independent variables separately and in a combination form (i.e., when the two are analyzed together) are necessarily demanded in interactive single-subject research design. This can only be done by varying or changing only one of the independent variable at a time which is a cardinal rule in single-subject research (Sternberg, 2006, Reisberg, 2006, Kantowitz, Roediger III and Elmes, 2005 and Christensen, 1985). To achieve this condition, two independent subjects must be studied contemporaneously with each undergoing treatment with a separate or different independent variable. Therefore, the entire sequence of phases in which the influence of each independent variable is tested separately and in combination must be able to allow for the influence of the interaction of the



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two independent variables to be compared with the effect of each of the variables separately. This accounts for why the effect of treatment B (concrete reinforcement) was independently investigated, and then the combined effect of treatments B and C was compared with that of treatment B alone for one subject, Dan. Similarly, the effect of treatment C (verbal reinforcement) was consequently investigated independently, and then the interactive effect of treatments B and C was identified and compared with that of treatment C for a different subject, Bob. It is only in this way that it was possible to ascertain that the combined or interactive effect of B and C treatments is radically greater than the effect of only either treatment B or C on the dependent variable consistently for both Dan and Bob in the example illustrated above.

The essence of the indispensability of two subjects in this single-subject design is that if the interactive effects of B and C treatments were found to be far greater or only in one subject (say Dan) than in the other subject (Bob), then the interactive effect does not exist at all because what is seen as interactive effect in Dan can more parsimoniously and correctly be attributable to only the treatment B that only Dan was exposed to severally. The reason being that the effect of treatment B in this scenario must have been so great, powerful and overwhelming, that the influence or effect of treatment C was swallowed by it.

**Limitations of Interactive Design**

There are three major shortcomings or limitations of interactive single-subject research design.

i. The design demands the use of two or more subjects because different subjects must be tested on each of the variables (Wasson, 2015).

ii The interactive effect can only be demonstrated in a situation that the two independent variables produce virtually equal effect on the common dependent variable. In a scenario that one of the independent variables produces overwhelming or maximum increment in behavior (the dependent variable), interactive effect cannot be established because even though the other independent variable has or contributes an effect, it will merely be consumed, swallowed or subsumed by the independent variable with an overwhelming effect (Shaughnessy, Zechmeister, & Zechmeister, 2000).

iii A third limitation of interaction design is that it requires withdrawal of two single treatments and one combined treatment that results in reversal of already gained acceptable behavior (Briggs, Ololube, & Kpolovie, 2014).

**Alternating-Treatments Design**

Alternating-treatments design of single-subject research is used to investigate the relative effectiveness of two experimental treatment or intervention conditions by alternately presenting the two experimental conditions to one subject in accordance with A→B→→A counterbalancing after establishment of the subject's baseline performance with respect to the dependent variable under study. This design first of all determines baseline with several pretreatment measurements, and then introduces two experimental treatments in an alternating sequence. The alternation sequence takes the form of B→A→A→B counterbalancing in which carry-over effect and sequencing effect are balanced out (Schiefelbein, & Farrell, 1990; Johnson, & Christensen, 2008). Carry-over and sequencing effects are balanced out with the administration of treatment A that is followed by administration of treatment B in the first part; and the presentation of treatment B that is followed by presenting treatment A in the second part of the experimental conditions. At each period that the subject is exposed to a treatment,


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series of observations or measurements are taken. The days and/or times of data collection are equally alternated to prevent the effect of specific days or times on the evaluation subject's behavior (Kpolovie, & Ololube, 2013). Where two research assistants are to be used for data collection, they are equally alternated to cut across the two experimental treatment conditions.

**Example of alternating-treatments design**

The modus operandi of a single-subject alternating-treatments design is exemplified in **Figure 6**, which represents the relative effectiveness of drug therapy and logotherapy in the cure of Omone Bright's depression. The counterbalancing order adopted in the study is A→B→→A→B→A→→B that forms two complete order of presenting treatment A (drug therapy) and treatment B (logotherapy) to him. Depression is a state of sadness, gloom, pessimistic ideation, feelings of worthlessness and guilt, with diminished ability to think or concentrate, and loss of interest or pleasure in normally enjoyable activities. Drug therapy is the use of stimulant chemical substance formulated exclusively for instant temporary reduction, cure and prevention of depression. Logotherapy is a psychological attempt for restoration of a sense of meaning by encouraging meaningful and creative activities and experiences of art, nature and culture, as well as encouragement of self-acceptance and an appreciation of one's place in the world by a close study of one's own attitudes to work, love, and in life generally.

The experiment lasted for three weeks with Monday, Tuesday, Wednesday and Thursday of each week used. The first week was dedicated exclusively to gathering of stable baseline data through structured standard observation and administration of a reliable and valid Depressions Reduction Scale to the highly depressed subject, Omone Bright. The baselines scores revolved closely around 10. In the second week, the subject was exposed to the alternation of experimental treatment conditions that covered the first complete order of A→B→→A over the four days respectively. Recall that wile treatment A is the drug therapy, treatment B is the logotherapy. Three measurement of depression reduction was taken each day. While depression reduction rates during treatment A hovered closely around 50, the depression reduction levels were closely at 100 with treatment B. Even at this point, it could be concluded that the experimental treatment B (logotherapy) is much more effective than treatment A (drug therapy) which was by itself effective for the purpose as it consistently produced greater reduction level of depression than what it was at the baseline level (the typical level during the pretreatment period).

But to further confirm the superiority of treatment B over treatment A; the second complete order of B→A→A→B counterbalancing of experimental treatments was used in the third week for the four respective days. The same results were obtained with the effect of treatment B averaging 100, while that of treatment A was averaging 50. With this, it has become absolutely clear beyond all possible ambiguity that though drug therapy (experimental treatment A) moderately reduced depression, logotherapy (experimental treatment B) reduced Omone's depression almost completely.


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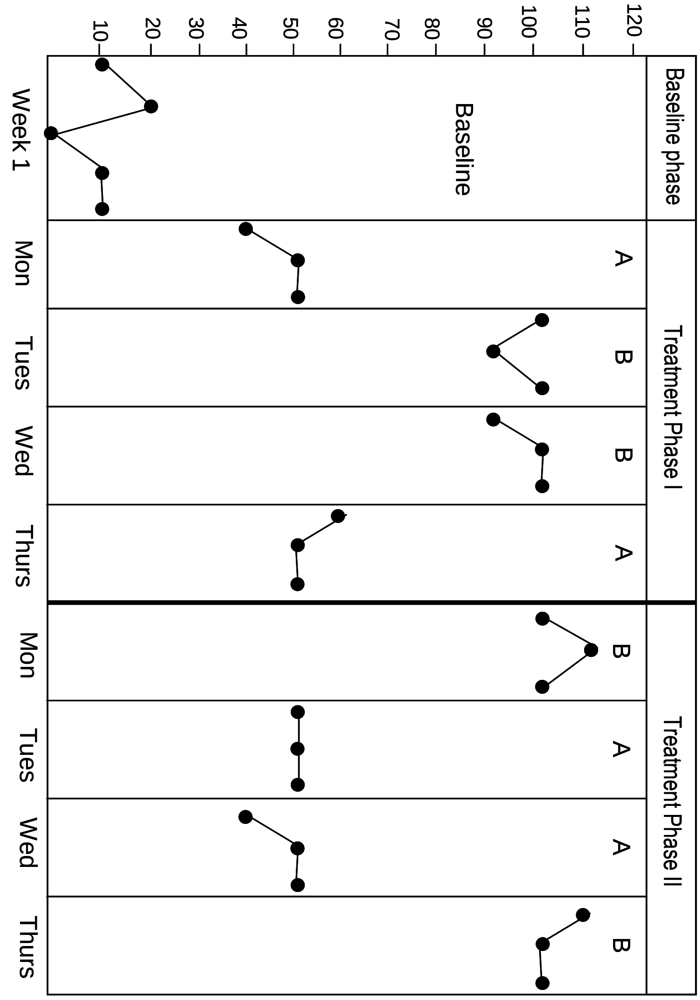


**Figure 6: Alternating design for relative effectiveness of drug therapy (A) and logotherapy (B) with ABBABAAB counterbalancing for reduction of Omone's depression.**

It must be noted that if the increase in the rate of depression reduction was caused by any extraneous variable like carry-over effect or sequencing effect, then there could have been a totally inverse pattern of the effects of treatments A and B between the ABBA and BAAB order of treatments alternation sequences because the two phases of treatment alternation were counterbalanced. Apart from that, even with the first ABBA phase of treatment, Omone's depression reduction level could have remained at 100 during the second presentation of treatment A. The same could have been true during the two exposures of the subject to treatment A at the second treatment phase of BAAB. Allowing at least one whole night to pass before the switching over from one treatment to the other was carefully built into the design for further avoidance of possibility of one treatment influencing the other. To control for probability of the Omone's being more depressed on some specific days of the week than others, there was incorporation of alternation of the days across the treatments such that each of the days over the two weeks treatment period got both treatments A and B administered to the subject. Therefore, the results of the investigation are definitely the causal effects of the manipulation of the independent variables (treatments A and B), and nothing else, on the dependent variable (reduction of depression). The treatment B (logotherapy) is unquestionably more effective in reduction of depression than treatment A (drug therapy).


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### Strengths and weaknesses of Alternating-treatments Design

Through the crucial differential response of the subject to the two alternation of experimental treatments, the single-subject alternating treatment design can be used to successfully isolate the most effective treatment condition without requiring a withdrawal of desirable therapeutic gains. Also, with the design, comparison of the effectiveness of two treatments is accomplished rapidly with one subject. In addition, it can even be done without necessarily colleting baseline data on the subject, if the researcher so wishes. Whenever effectiveness of different treatment conditions are to be experimentally compared with single-subject research, the alternating-treatment design should necessarily be used.

The weak aspect of this design is the possibility of multiple-treatments interference effect occurring in spite of the counterbalancing. Multiple treatments interference refers to a situation that the two treatment conditions affect each other greatly or combine to produce interactive effect on the dependent variable. Another limitation of the design is that it is very cumbersome to implement due to the need to both counterbalance stimulus while simultaneously alternating-treatment conditions.

### Changing-Criterion Design

Changing-criterion design is an experimental single-subject research in which establishment of baseline is followed by series of upward graduated experimental treatments that each successive phase demands and is accorded a step-by-step increment in the criterion measure. The experimental control of this design is demonstrated via successive replication with higher-order change in the target behavior which systematically improves with each stepwise upward difficulty in the criterion. Christensen (1985: 230) defined it simply as "a single-subject design in which a subject's behavior is gradually shaped by changing the criterion for success during successive treatment periods".

This design has a myriad of phases after the baseline with each demanding greater desirable output on the part of the subject in order to be rewarded. The experimental reinforcement could be exactly the same across the various phases, but the criterion set for the subject to accomplish in each successive phase is logically and systematically higher or more rigorous and demanding. At each phase, the subject is tested or observed severally and recorded until a stability of success is attained (Siegle, 2015). On such accomplishment, he is reinforced or rewarded, usually with concrete reinforcement; and then shown or told the next higher criterion to be achieved in the proceeding phase before the delivery of another unit of the reward. The procedure is repeated until maximum actualization of the targeted behavior that serves as the dependent variable (Ololube, & Kpolovie, 2012).

### Successful application of changing-criterion design

Changing-criterion design of single-subject research is required for investigations that deal with step-by-step and phase-by-phase shaping or modification of the subject's behavior for better over a period of time. Also, when the therapeutic goal in investigating a phenomenon is step-by-step increments in accuracy, frequency and duration; the changing-criterion design is suitable. For an investigation that adopts changing-criterion design to be successful, four conditions must be met (Shultz, Whitney & Zickar, 2014).


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**Stability of baseline data**

To make rival explanations or hypotheses implausible in this design, enough baseline data must be collected until they become very stable over time. If this condition is not met, then extraneous variables like history and maturation could be seen as the causes of the change in the dependent variable, and not the manipulation of the independent variable.

**Length of treatment phases**

For plausibility of rival explanations to be ruled out, each phase of the experimental treatment must be sustained long enough for a new behavioural change to occur and become stabilized across series of trials, observations or measurements. This is because any fluctuation of newly acquired behavior between the old and new criterion levels is an indication that the cause-and-effect relationship between the independent and dependent variables at that particular phase is ambiguous, questionable, invalid and unreliable.

**Magnitude of change in the criterion**

The magnitude of successive upward variation in the criterion must be satisfactorily large enough to contemporaneously allow for both achievability and detectability of the required desirable behavior. It is only when the criterion change is achievable that it can be challenging to result in behavioural improvement that can be separately measured consistently across series of repeated testing at a particular phase. Without this condition, causality cannot be proved.

**Number of treatment phases**

The number of treatment phases denoted by how many times the criterion is changed must be many enough, say five, so that cause-and-effect relationship between the independent and dependent variables can be convincingly demonstrated beyond doubts. Since the step-by-step changes to be brought about in the subject through changing-criterion design are desirable changes; the more the number of phases that the changes are elicited and demonstrated to be irreversibly stable over repeated measurements, the less the plausibility of rival hypotheses aimed at disproving the causal link between the independent and dependent variables.

**Example of Changing-Criterion Design**

A hypothetical example of how changing-criterion design can be used to improve a primary III pupil's skills in mathematical operations is given in **Figure 7**. Monetary reinforcement of ₦100.00 for scoring 20% at phase 1, 40% at phase 2, 60% at phase 3, 80% at phase 4 and 100% at phase 5 in a 100 items test on mathematical operations of basic addition, subtraction, division and multiplication of whole numbers and fractions with the items arranged in their order of difficulty can be used for the purpose.



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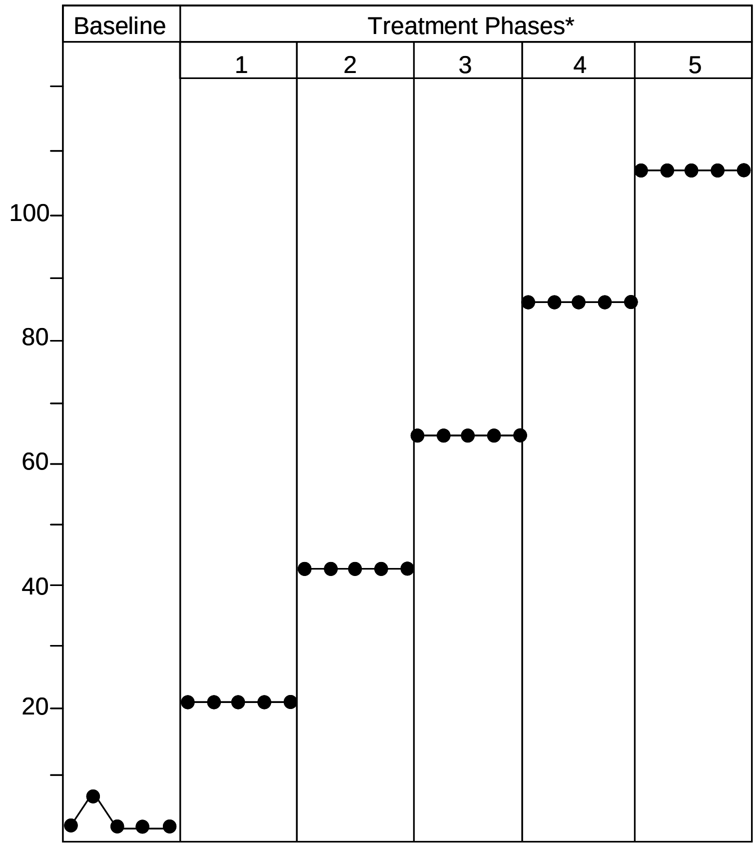


**Figure 7: Hypothetical example of changing-criterion design to improve a primary III pupil's skills in mathematical operations.**

## DATA ANALYSIS IN SINGLE-SUBJECT RESEARCH DESIGNS

Some of the underlying assumptions in multiple-subjects research do not apply in single-subject research. Consequently, a few data analysis techniques that are suitable in single-subject research are not appropriate for use in multiple-subjects research designs. While data analysis is treated in detail in another book by the author, some of the techniques for analyzing data collected in single-subject research are mention hereunder.

### Visual Analysis

Single-subject research designs offer much of value to clinical, educational, psychological, scientific and social science researchers who are concerned with the effects of experimental interventions or treatments upon the academic, clinical, social and other behavior performance of individual children and/or adults. Behavioural or health gains (adjustments for better behavior or health) occasioned by manipulation of the independent variables in single-subject designs are portrayed with visual analysis. Visual analysis of data refers to accurate graphical representation of the various measurements taken of a subject's behavior of interest or under scrutiny at the baseline and at the different treatment phases to clearly show the patterns, slopes, levels and trends of the behavioural changes demonstrated by the subject across all the phases of the investigation with particular reference to the differences between the pre-intervention


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(baseline) and the experimental treatment phase or sessions (Wasson, 2015; Yin, 2013; World Bank 2015).

Visual analysis demands greatest care and accuracy in the graphical presentation of single-subject research data to ensure prevention or avoidance of misinterpretation that is capable of leading to errors in concluding effects which may be assumed, but in reality, are not present. This is referred to as Type I error (false rejection). Without the great carefulness and accuracy that graphic presentation of single-subject data demands, a converse error, that of not noticing an effect of the treatment condition, when indeed the effect does exist, can also be made. This is termed Type II error (false acceptance).

As a matter of necessity, visual analysis should compulsorily be drawn on graph paper so that the conditions of accuracy and carefulness can better be attained. For misinterpretation of data not to occur in single-subject research, visual analysis of data demands that the variables and their various observed or measured points be carefully and accurately graphed by consistently using appropriate scales both at the ordinate and abscissa. The ordinate is the vertical axis or Y-axis along which the dependent variable is displayed. On the other hand, the abscissa is the horizontal axis or X-axis that is used to indicate sequence of time, such as phases, sessions, days, weeks, months or trials. A rough rule of thumb here is to have the horizontal axis anywhere from one and one-half (i.e., one and a half) to two times as long as the vertical axis (Sternberg, 2006; Fraenkel and Wallen, 2003; Babbie, 2007; Reisberg, 2006; Kantowitz, Roediger III and Elmes, 2005; Myers, 1987 and Keeves, 1990). Then, condition lines which are normally vertical are used to separate the various conditions of specific phases of the investigation, beginning with the baseline phase or condition. Data points collected on the dependent variable at various times of the investigation are represented with round dots. The round dots are placed on the graph at the exact point of intersection of the magnitude of each data point along the ordinate and the time it was collected along the abscissa. Finally, the data points for each phase of the investigation are orderly connected with linking lines to obtrusively depict trends, slopes, levels and patterns of the dependent variable across all the phases in the investigation.

Use of visual analysis for single-subject research data is so indispensable and important that even critics of the technique acknowledge it. For example, even Sharpley (1990, 582) who criticized use of visual analysis in single-subject research had cause to conclude in favor of using visual analysis when he affirmatively wrote:

> Before leaving this issue of visual analysis, it is worth commenting that there are some cases when visual analysis is appropriate (in single-subject research). For example, when the baseline data indicate a zero or 100 percent occurrence of the behavior being examined, and this is followed by a dramatic increase (or decrease) in that behavior, then the effectiveness of the intervention under scrutiny may be accepted as demonstrated. Generalizability is another matter however, and would be enhanced by replication of the effect with other subjects or across other settings, thus demonstrating that the effect noted in one case and under certain circumstances is not selectively confined to that person or those circumstances.


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**Statistical Analysis**

The traditional statistics used and which can still be employed for analyzing data in single-subject research are t-test, analysis of variance and occasionally regression (Kpolovie, 2012a). These are based upon the least squares model which assumes that the data examined are independent of each other. Applying these statistical techniques to single-subject research data therefore implies that the measurements or observations collected repeatedly about the subject under scrutiny must all be independent (Shultz, Whitney & Zickar, 2014). However, this is not necessarily so all the time as there is bound to be non-independence in the data in some cases. Where non-independence occurs, the data are said to be ***autocorrelation data*** (Keller and Warrack, 2003). When non-independence exists, autocorrelation analysis could be used. Autocorrelation analysis is a serial correlation which is the correlation between data collected at the baseline phase and at each of the experimental intervention or treatment phases (Meyers, Gamst, & Guarino, 2013). This is known as the second-order correlation. There is also the first-order correlation which is the correlation of the baseline phase data with the first treatment phase data; between the first treatment phase data and data at the second treatment phase; between the second treatment phase data and data in the third intervention phase; and so on. A highly positive correlation is indicative of prediction of performance in one phase from the previous phase, or is predictive of the subject's future performance when the intervention condition is present. A highly negative correlation is indicative that the treatment has an effect on the behavior of the subject (Wasson, 2015; Yin, 2013; World Bank 2015).

**Interrupted Time-Series Statistic**

Interrupted time-series statistic is a non-traditional statistic that is very suitable for analyzing data from single-subject design. Interrupted time-series statistics is used to calculate the level of autocorrelation that is present in the baseline data and in the intervention data and to compare the baseline data with the experimental intervention data for whether significant t-values exist in the levels and slopes between the two phases. Any significant t-value in favor of the treatment denotes an indisputable causal effect of the experimental intervention. According to Sharpley (1990:585-586), "The interrupted time-series statistic does not assume independence of observations, and calculates the degree of correlation between the points in the data series before testing for intervention effects. This procedure is therefore recommended when data are collected upon the same subject(s) over time and where autocorrelation may be expected". Generally, time series analysis of single-subject research data consists of long-term trend, cyclical variation, seasonal variation and random variation; that use smoothing techniques (moving averages and exponential smoothing) as well as trend/seasonal effects for accurate forecasting and modeling of the subject's future behavioural characteristics via deseasonalizing (production of seasonally adjusted time series) and autoregressive model (Keller and Warrack, 2003 and Panneerselvam, 2009).

**Therapeutic Criterion Study**

This strategy is not statistical directly; but very effective in validly and reliably concluding correctly that the experimental treatment has an effect on the subject's behavior because it is based on a brief following to see that the subject has indeed demonstrated that the experimental treatment condition has eliminated the behavior disorder or has at least enhanced everyday functioning of the subject. Simply put, therapeutic criterion study is the practical clinical significance or value of the experimental treatment effect for the subject (Kpolovie, 2012a). Therapeutic criterion is established by including social validation, social comparison method,


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and subjective evaluation method into the single-subject research (Christensen, 1985: 238). While social validation is "determination that the treatment condition has significantly changed the subject's functioning", social comparison method is "a social validation method in which the subject is compared with non-deviant peers". Subjective evaluation method is "a social validation method in which other's views of the subject are assessed to see if those others perceive a change in behavior (of the subject)". That is, in the first case (social validation), relevant post experiment information are taken to ascertain whether the treatment in the experiment has actually produced important change in the subject's day-to-day functioning in life. The second method (social comparison method) requires additional or post-experiment comparison of the subject's behavior before, during and after the experimental treatment with the behavior of his peers who are non-deviants with respect to the behavior under scrutiny and were therefore not subjected to the experimental treatment to see whether the subject now behaves like them. The last technique (subjective evaluation method) is used to ascertain whether the experimental treatment has caused great qualitative changes in the subject after the experiment as perceived by other people who see the subject (Ololube, & Kpolovie, 2012). This is accomplished by asking individuals who normally interact with the subject and who are in the right position to assess the subject's behavior to actually appraise his functioning after the experiment on a rating scale.

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