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Music Tempo and Manufacturing Efficiency Ratio: An Experimental Research

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Abstract

This paper aims to contribute to the success of multinational organizations (MO). Despite the vast quantitative and qualitative data explaining the reasons for high or low productivity in the workplace (both, public and private organizations), more precise correlations are urgently required to maximize MO productivity ratios and pair it with the speed of today's hyper- competitive economy. The scope of this research is limited to the *physical conditions* in the workplace, specifically the one related to the noise level, in this case, the type of music played on the manufacturing floor. An experimental quantitative research is conducted to describe the relationship between *music tempo* (IV) and *efficiency* (DV). To examine this concept, the present study uses a manufacturing plant located in Rio Grande, Tierra del Fuego, Argentina. Efficiency ratio of four assembly lines with 30 workers randomly selected each will be measured while listening to white noise (M_O), slow music (M_S), and fast music (M_F). The results suggest music tempo correlates positively with efficiency ratios, the faster the music tempo is, the higher efficiency (up to a point where efficiency actually starts decreasing as music tempo increases).

Keywords: Multinational organizations; Productivity; Efficiency; Music tempo; Value maximization

Introduction

The world is facing several challenges, uncontrolled gains on carbon dioxide (CO_2) emissions, high food prices, water scarcity, aging populations, poor education, gender issues, unbalanced income distribution, and unprecedented unemployment rates, affecting both developed and developing countries [1]. Resolving these challenges depends crucially on three factors, quality of leaders, quality of institutions, and quality of education, these factors are related positively to the pace of economic development [2]. Innovation is increasingly perceived as essential for tackling such challenges [3], and people are at the heart of the innovation process. "Education systems play a fundamental role in the development of a highly qualified and flexible labor force" [4].

According to Hunya, multinational organizations (MO) represent the most operative and rationalized system to promote economic development, technological transfer, and deepening globalization (2002). Although this assertion is correct by looking at the tangible benefits MO have produced in the economy; this *rationalized system* is far from being sufficient to resolve the fundamental issues humanity faces today (e.g., poverty, hunger, illness, and reduced opportunities to develop intellectual, and psychological skills of individuals). Dynamics of the business environment are paired with the inherent complexity of globalization, generating the imminent need to match (1) language and cultural values barriers –foundation of mental programs frameworks [5], with (2) ethical global business decision mechanisms. This actuality represents probably the biggest challenge MO face today to survive and prosper. After the collapse of the Soviet Bloc in 1991, almost all countries in the world were integrated into one *global system of trade* where foreign investment was supported by institutional changes facilitating freer movement of raw materials, products and services among countries [6]. Most MO are *over-managed* and *under-led* [5]. Leaders own the definition of incentive, and compensation structures to drive behaviors, priorities, and ultimately decision- making criteria to rise the probability MO will deliver long-term health, civility, sustainability, and profits.

Sampling and Data Collection Approach

Variables definition

This study looks to examine how playing music can alter the speed of movement of the line operators in the electromechanical assembly of a factory. The variables of the experiment are, (1) music tempo (IV), it is a quantitative continuous variable, for which the number represents a quantity that can be described in terms of order, spread between numbers, and/relatives amounts [7]. Tempo is the pace of a piece of music [8]. Beats per minute (bpm) convention is used in research on musical tempo, but tempo is also represented as the time interval between successive beats [8]. It is acknowledged tempo is one of several intrinsic features of music (e.g., rhythm, grouping, beat, and meter), and it is considered the foundation of music measure as it defines the *speed of music* [9]. In a related vein, Gluch' research demonstrated metrical tempos represent a relevant cue to understand the relationship between music tempo and "willingness of the body to move" [10], yet literature in workforce settings have failed to show results in agreement [11]. For the purpose of this research, music played on the production floor will have no lyrics, only tunes, in so doing; extraneous variables (e.g., emotional reaction to music lyrics content) and confounding factors (e.g., operators' mood, fatigue, stress, workload, weather, etc.) will be minimized. (2) Efficiency (DV) is also a quantitative continuous variable, and it measures the effect of the IV, and it is defined as the number of units assembled by the production lines per unit of time. This field experiment will be done using a real-life setting on a manufacturing facility in Argentina. IV will be manipulated actively (e.g., playing

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white noise (MO), slow music (MS), and fast music (MF)) to observe the changes in the DV (efficiency ratio of five production lines –each with 30 operators randomly selected). There are not mediating neither moderator variables as the setting in the manufacturing floor as shown in Figure 1 to ensures no other variables influence the efficiency ratio.

Levels of measurement of the variables

This experimental study uses ordinal and ratio measurement levels. IV, music tempo, is measured at an *ordinal level* when it is classified in two categories slow (MS: music tempo below 120 bpm), and fast (MF: music tempo above 120 bpm). In the same vein, DV is measured at a *ratio level* when it correlated the number of pieces produced (finished goods) per assembly line per unit of time (hour) using a ratio. The absolute zero is the efficiency of units produced in current conditions (MO) in an hour period –zero means the absolutely no amount of whatever the variable indicates [7]. This level of measurement will allow determining how many times or what percentage efficiency varies when assembly lines are exposed to different music tempo. Of course, the numbers also are mutually exclusive, are exhaustive, have order, and there are equal gaps. This is found coherent with the type of research design selected for this research, ratio data have the highest level of measurement [12], ratios between measurements are meaningful because there is a starting point and allow comparing them to see if they were equal or not, larger or smaller than another, added or subtracted, multiplied or divided.

Sampling and data collection approach

According to Gordon et al. [13] MO in the *electronic manufacturing* and *original design manufacturing* industry (EMS and ODM respectively) are "(…) the backbone of computers and electronics production globally, providing essential design, manufacturing, and assembly services to hardware companies" (p. 32). This industry is established primarily in Asian countries –approx. 70% of world capacity, and employs more than five million people [13]. This research looks to contribute to the knowledge of reliable causal relations to improve MO financial and operational performance, and ultimately, improve the quality of life of the people depending on this large industry. In like fashion, this investigation aims to draw a representative sample from the population not only to save time and money, but also to improve validity and generalizability. A probability sampling seems ideal to achieve the purpose of the research (i.e., measure quantitatively the *cause and effect* relationship between the increment of units produced per unit of time (DV), and the music tempo (IV) in an electromechanical assembly plant) as shown in Appendix A. The goal is to generalize from a particular sample to a population, consequently randomly selected workers doing repetitive movements to assemble electromechanical devices in a progressive production flow are studied (Figure 2).

Sampling design in detail

This quantitative research employs a cluster sampling procedure in which elements (assembly lines) of the population (manufacturing facility with 16 assembly lines) are randomly selected in naturally occurring groups (Lines A, B, C, and D called clusters). Cluster sampling considers the selection of population elements not individually but in aggregates, in the context of this study, space-based following the plant layout and assembly lines flow as shown in Figure 1. Within-cluster differences are high while the so-called, the between-cluster differences are small. Clusters are alike to each other; each assembly line consists of 30 randomly selected heterogeneous operators as shown in Table 1.

This probability sampling method ensures the cost, the time,

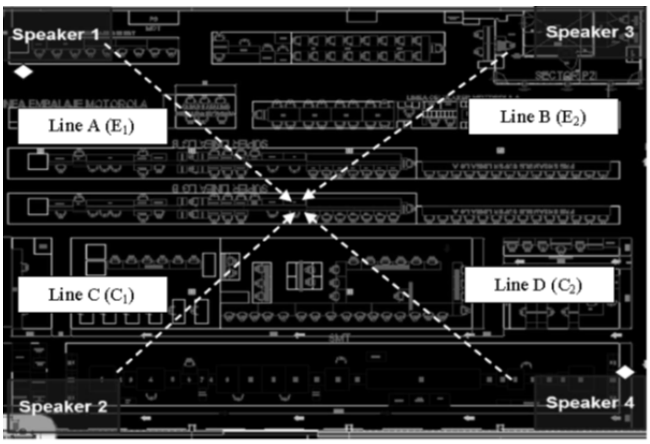

Figure 1: Music Setup in the Production Floor layout. Four speakers are positioned in a fix location creating a quadraphonic surround sound effect where volume level is the same in any operators' position on the floor. White rhombus identify the location of the decibel sound meters used to ensure volume level is the same.

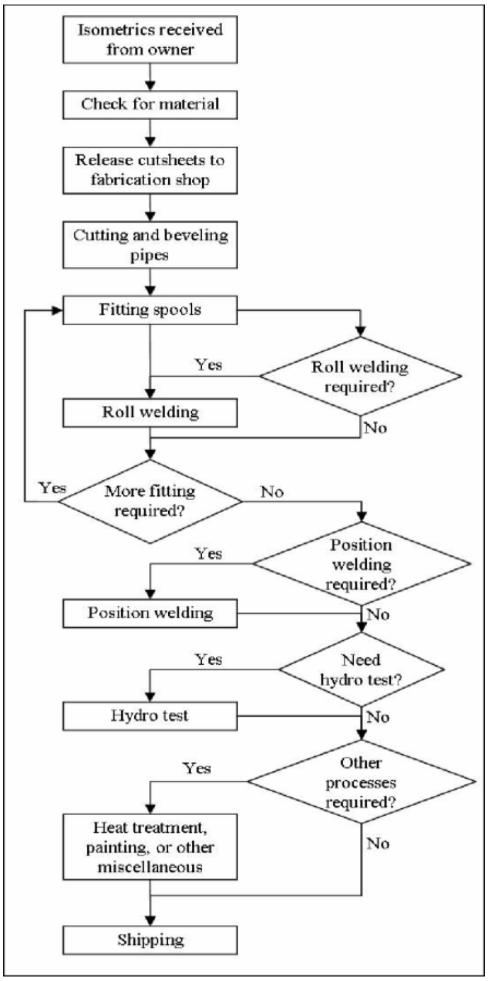

Figure 2: Electromechanical processes of 30 Progressive Operations. This process aims to illustrate the sequence of operations to manufacture the electric device in question. This study measures the variation in efficiency as the music tempo changes.

Characteristic	Population	Sample	Variation ratio[1]
Line Workers Age			
Between 18 and 25	40%	37.5%	+2.5%
Between 26 and 30	25%	26.5%	+1.5%
Between 31 and 35	20%	20%	0%
Between 36 and 40	10%	11.5%	+1.5%
Older than 41	5%	4.5%	-0.5%
Line Workers Gender			
Male Female	45% 55%	44% 56%	-1.0% +1.0%
Line Workers Education Elementary only High School College Higher	78% 19% 2.5% 0.5%	79% 19% 1.5% 0.5%	+1.0% 0% -1.5% 0%
Line Workers Ethnicity			
Local[2] Foreigner[3]	35% 65%	34% 66%	-1.0% +1.0%
Line Workers Job Skills			
Employed less than 6 months Employed between 7 and 12 months Employed more than 13 months	5% 75% 20%	4% 76% 20%	-1.0% +1.0% 0%

Note: Information gathered from the Human Resource Department of the selected MO. Line workers refer to the employees working in the production floor assembling electromechanical devices.

[1]Also called sample error.

[2]People born in Rio Grande, Tierra del Fuego, Argentina.

[3]People born outside of Rio Grande, Tierra del Fuego, Argentina. Based on the marginal variation ratio, population and sampling are found consonant; sample seems to have very similar characteristics to the population they belong.

Table 1: Population and sample composition comparison.

Step	Description	Definition in this study
1	Target population	Electromechanical Assembly MO in Rio Grande, Tierra del Fuego, Argentina. Population is separated into 16 clusters; this study will sample four of them.
2	Desired sample size	25% of the assembly lines in this factory (*four of 16*) are the selected sample; these lines are selected based on a proportional representation of the clusters (lines) in the total sample.
3	Sampling frame development of clusters	Each cluster consists of *30 workers*. This factory employs 480 workers in their assembly lines, the four lines selected are split through the manufacturing floor, allowing a controlled environment to measure accurately the change in DV (efficiency) when varying the IV (music tempo), minimizing the effects of extraneous or confounding variables and the distortion of observations accuracy. Four selected lines represent an equal proportion of employees than it is the number of lines selected, this is 30 employees per line equal (4*30=120 employees), and this is 25% of the total headcount of the factory.
4	Under coverage, over coverage, multiple coverage and clustering sampling evaluation	Clusters are heterogeneous as the population, workers are assigned randomly to the assembly lines, a worker cannot be in another line at the same time, and clusters are mutually exclusive and collectively exhaustive.
5	Number of clusters selection	Each cluster itself represent a 6.25% of the population (1/16=0.0625). Consequently, four clusters cover 25% of the population. This provides sufficient balance between the number of clusters and the precision expected of the measurements (efficiency) to taken on each cluster.

Note: A cluster is defined as an aggregate or intact grouping of the population.

Table 2: Cluster sample procedure.

and the labor required to collect data are minimized, as no special arrangements are mandatory to gather data, assembly lines are geographically defined and distributed in a way music tempo can be modified accurately without contaminating other clusters. In a related vein, unlike simple random sampling, cluster sampling is easier to implement and permits subsequent sampling because the sampled clusters are aggregates of elements (assembly lines). This sampling approach allows estimating characteristics of the clusters as well as the population, and lastly, cluster sampling does not require a sampling frame of all of the elements in the target population. Conversely, it is recognized this sampling method may introduced additional complexity in analyzing data, however, with the described descriptive and inferential statistical analysis described in precedent sections, this problem is resolved adequately. Sampling errors using this sampling approach are diminished as cluster size is exactly the same (30 workers per assembly line), and increasing the number of cluster is always a possibility to resolve any concern about this as given in Table 2. In summary, this sampling method decreased the cost and increased operational efficiency without sacrificing precision and representation of the sampled subjects.

This investigation uses two *experimental groups* (E1 represented by Line A, and E2 represented Line B), and two *control groups* (C1 denoted by Line C, and C2 denoted by Line D). Each group will complete *posttest* measures – varying IV, music tempo, from slow (MS) to fast (MF), but only groups E1 and C1 complete *pretest* measures and this way, by so doing, the *pretest sensitization effect* will be reduced. Each group will consist of a production line, which includes 30 operators; in like manner, production lines are distributed in a way no interference between lines will occur, each line is isolated and the evaluation of the subject groups can be done independently – Lines A, B, C and D are secluded as shown in . Each line will produce 240 measurements of the DV. Further, efficiency measure will be downloaded from the factory' ERP system, considering a period of two weeks under treatment one (MS), and two weeks of treatment two (MF), each week consist of 80 measures, 16 h per day (work schedule) times five days per week. Three weeks should be enough to eliminate influence of potential *extraneous variables* related to the DV (e.g., emotional reaction to music lyrics content) and *confounding factors* (e.g., operators' mood, fatigue, stress, workload, weather, etc.). Figure 2 illustrates the experiment design in detail, and allows evaluating the magnitude of effects because of pretesting, treatment, maturation, and history separately. For instance, EF1 represents pretesting, treatment, maturation, and history; EF2 denotes pretesting, maturation and history; EF3 illustrates the treatment, maturation and history; and EF4 exemplifies maturation and history. With this data, the difference between EF3 and EF4 (i.e., EF3-EF4) one could evaluate the effect of the treatment (music tempo variation) alone, while EF2-EF4 the effect of pretesting, and EF1-EF2-EF3 the result of interaction of pretesting and treatment as shown in Figure 3.

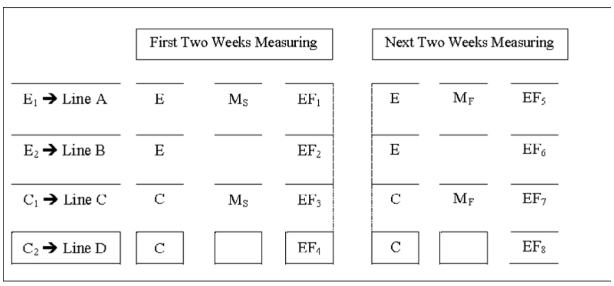

Figure 3: Experimental Design where E denotes the randomized experimental groups (groups are equal except for random differences). C denotes the randomized control groups (groups are similar except for random variations). Subscript indicates the number of groups involved in the study. EF stands for measurement of units produced (efficiency), pretest or posttest. Index indicates efficiency ratio per cluster sampled -cluster is used indifferently as group or assembly line. M_S represent the experimental treatment (playing slow music tempo on the manufacturing floor).

Method

Research approaches or designs are approximately orthogonal to the techniques of data collection, and thus, in theory, any data collection technique could be used with any approach to research [12]. This investigation relied extensively on direct observation to obtain richer and more in-depth information, this is found as strength as experimental quantitative research is expected to "gather data from primary sources" [14]. Perhaps some of the alleged weaknesses associated with observation method, for example lack of control variables in the natural setting, researcher own values and ethics affecting her objectivity, and failure to observe some activities because of distractions [15] may discourage researchers to pursue this data collection technique. This is not the case of this study, instead, it aims to prevent contradictory or vague findings, questionable data, unclear statements about its intent and purpose, lack of full disclosure of the data collection procedure or inarticulate rendering of the research problem. Ethical considerations are taken to respect the rights of the participants (e.g., this study is conducted in a manufacturing plant operating under normal conditions, no special settings or arrangement were made –nor even awareness to the subjects is provided; honor the requests and restrictions of the research site, and reporting the research thoroughly and honestly. As noted earlier, this experimental research utilizes a *between-subjects* approach and to minimize the *pretest sensitization* issue derived from the subjects' awareness of the experiment and expected results after the change of the IV, a *Solomon Four-Group* design is applied in each phase of the experiment. In general, this design enhances both internal and external validity and eases the evaluation of magnitudes of the effects derived from the treatment, maturation, history, and pretesting as shown in Appendix B. Tables 3-7 depict the details of the experiment phases, including sample sizes, sequence of treatments, and experimentation execution schedule. Tables 3 and 4 describe the sequence of the experiment to resolve *Research Question No. 1* (i.e., how music tempo affects the efficiency of line operators to produce electromechanical assemblies? With H10: μE1=μE2 and H1A: μE1≠μE2).

Tables 5 and 6 do the same for *Research Question No. 2* (i.e., will the absence of music elicit higher efficiency ratios than those obtained when playing slow music tempo? With H20: μC1=μC2 and H2A: μC1≠μC2).

Tables 7 describes the sequence of the experiment to resolve

Assignment	Group	Pre-test	Treatment WW10	Post-test
R	E_1 →Line A (n=30)	M_S	Slow music tempo	M_S
R	E2 →Line B(n=30)		-	
R	C1 →Line C (n=30)	M_S	Slow music tempo	M_S
R	C2 →Line D (n=30)		-	

Note: R denotes the random assignment of operators to the production floor (operators' gender, age, nationality; E represents experimental groups, C indicates control groups, MS denotes the treatment to be applied to the sample, slow music tempo, WW means work week, numbers next to WW represents the dates when the experiment will be executed.

Table 3: Phase 1 of the experiment: slow music tempo.

Assignment	Group	Pre-test	Treatment WW10	Post-test
R	E1 →Line A (n=30)	MF	Fast music tempo	MF
R	E2 →Line B (n=30)		-	
R	C1 →Line C (n=30)	MF	Fast music tempo	MF
R	C2 →Line D (n=30)		-	

Note: R denotes the random assignment of operators to the production floor (operators' gender, age, nationality; E represents experimental groups, C indicates control groups, MS denotes the treatment to be applied to the sample, slow music tempo, WW means work week, numbers next to WW represents the dates when the experiment will be executed.

Table 4: Phase 2 of the Experiment: Fast Music Tempo.

Assignment	Group	Pre-test	Treatment WW10	Post-test
R	E1 →Line A (n=30)	MO	White noise	MO
R	E2 →Line B (n=30)		-	
R	C1 →Line C (n=30)	MO	White noise	MO
R	C2 →Line D (n=30)		-	

Note: R denotes the random assignment of operators to the production floor (operators' gender, age, nationality; E represents experimental groups, C indicates control groups, MS denotes the treatment to be applied to the sample, slow music tempo, WW means work week, numbers next to WW represents the dates when the experiment will be executed.

Table 5: Phase 3 of the Experiment: White Noise.

Assignment	Group	Pre-test	Treatment WW10	Post-test
R	E1 →Line A (n=30)	MO	Slow music tempo	MS
R	E2 →Line B (n=30)		-	
R	C1 →Line C (n=30)	MO	Slow music tempo	MS
R	C2 →Line D (n=30)			

Note: R denotes the random assignment of operators to the production floor (operators' gender, age, nationality; E represents experimental groups, C indicates control groups, MS denotes the treatment to be applied to the sample, slow music tempo, WW means work week, numbers next to WW represents the dates when the experiment will be executed.

Table 6: Phase 4 of the Experiment: slow music tempo.

Assignment	Group	Pre-test	Treatment WW10	Post-test
R	E1 →Line A (n=30)	MF	Fast music tempo	MF
R	E2 →Line B (n=30)		-	
R	C1 →Line C (n=30)	MF	Fast music tempo	MF
R	C2 →Line D (n=30)		-	

Note: R denotes the random assignment of operators to the production floor (operators' gender, age, nationality; E represents experimental groups, C indicates control groups, MS denotes the treatment to be applied to the sample, slow music tempo, WW means work week, numbers next to WW represents the dates when the experiment will be executed.

Table 7: Phase 5 of the Experiment: Fast Music Tempo Variation.

Research Question No. 3 (i.e., will the efficiency variance continuously change? With H30: $\sigma E1 \leq \sigma E2$ and H3A: $\sigma E1 > \sigma E2$).

Justification of Focus and Form of Research Questions and Hypotheses

MO are the blood of modern and open economies [16]. As globalization increases, the pressure to the MO does too [17]. The shift in the economy (local to global) has changed the paradigms of comparative advantages. The current archetype (i.e., *knowledge-based* companies) opens an unprecedented opportunity for MO to increase their *efficiency ratios*. The novelty of this quantitative experimental study is the introduction of a comprehensive concept, *MO Operating System* (MOS), defined as the combination of (1) MO' leadership effectiveness, (2) supply chain success, and (3) re-engineering capacity efficiency. Understanding the relationship between causal variables (e.g., physical conditions of the factories) and their efficiency ratios provide MO with reliable predictors to maximize their value creation. Research questions appoint to provide substantive information to understand better how simple changes MO can do to improve their operation and financial performance, for example, changing the *music tempo* in their manufacturing floors. It is acknowledged tempo is one of the several intrinsic features of music (e.g., rhythm, grouping, beat, and meter), but tempo is considered the foundation of music measure as it defines the *speed of music* [9]. This study focuses on this intrinsic feature to create an experiment that setup emulates the reality of manufacturing factories entirely, enabling the potential generalization of results. Different stakeholders of MO can find value in this study, for example, for investors; they could benefit from higher efficiency ratios and profits while employees can benefit from less stressful or humdrum work environment. However, there is a fine line this study aims to resolve too, excess of music tempo or louder volume, could affect product quality because of workers' distractions, which generate production disruptions, and lower efficiency ratios negatively.

Logic of Hypotheses Testing

Alternative hypotheses H1A (assembly lines exposed to slow music tempo (MS) will produce less units (E) than those exposed to faster music tempo (MF): H1A: $\mu E1 \neq \mu E2$), and H2A (assembly lines exposed to white noise (MO) will produce more units (E) than those exposed to slow music tempo (MS): H2A: $\mu C1 \neq \mu C2$). Both alternative hypotheses are *non-directional* as they only compare the means of the selected samples (defining if they are equal or not). On the other hand, H3A (assembly lines exposed to fast music tempo (MF) will keep the number of units produced (E) higher throughout the work shift: H3A: $\sigma E1 > \sigma E2$) is *directional*; as it aims to demonstrate the variation rate of the DV (efficiency ratio) in one population is greater than the other. It is acknowledged the implication of using a directional alternative hypothesis to resolve research question three, the gain in sensitivity of test is counteracted by the imminent limitation of generalizing the results, as they will lack sufficient scientific research foundation.

Considering the three sets of hypotheses (null and alternative) defined in this study, the logic to test them will follow the typical steps, (1) state the null and alternative hypotheses, (2) set the alpha level, (3) select the statistical test, (4) conduct the statistical test and determine the p-value, (5) compare p-value to the alpha level and apply decision rule one or two (i.e., one if *p*- value is equal or less than alpha level –in this case the null hypothesis is rejected; and two, if *p*-value is greater than alpha level a three steps approach –in this case the null hypothesis cannot be rejected), and (6) compute findings and interpret results. In this case, first step in the hypotheses testing process, it to test the null hypothesis that focuses on the first research question (i.e., H10:

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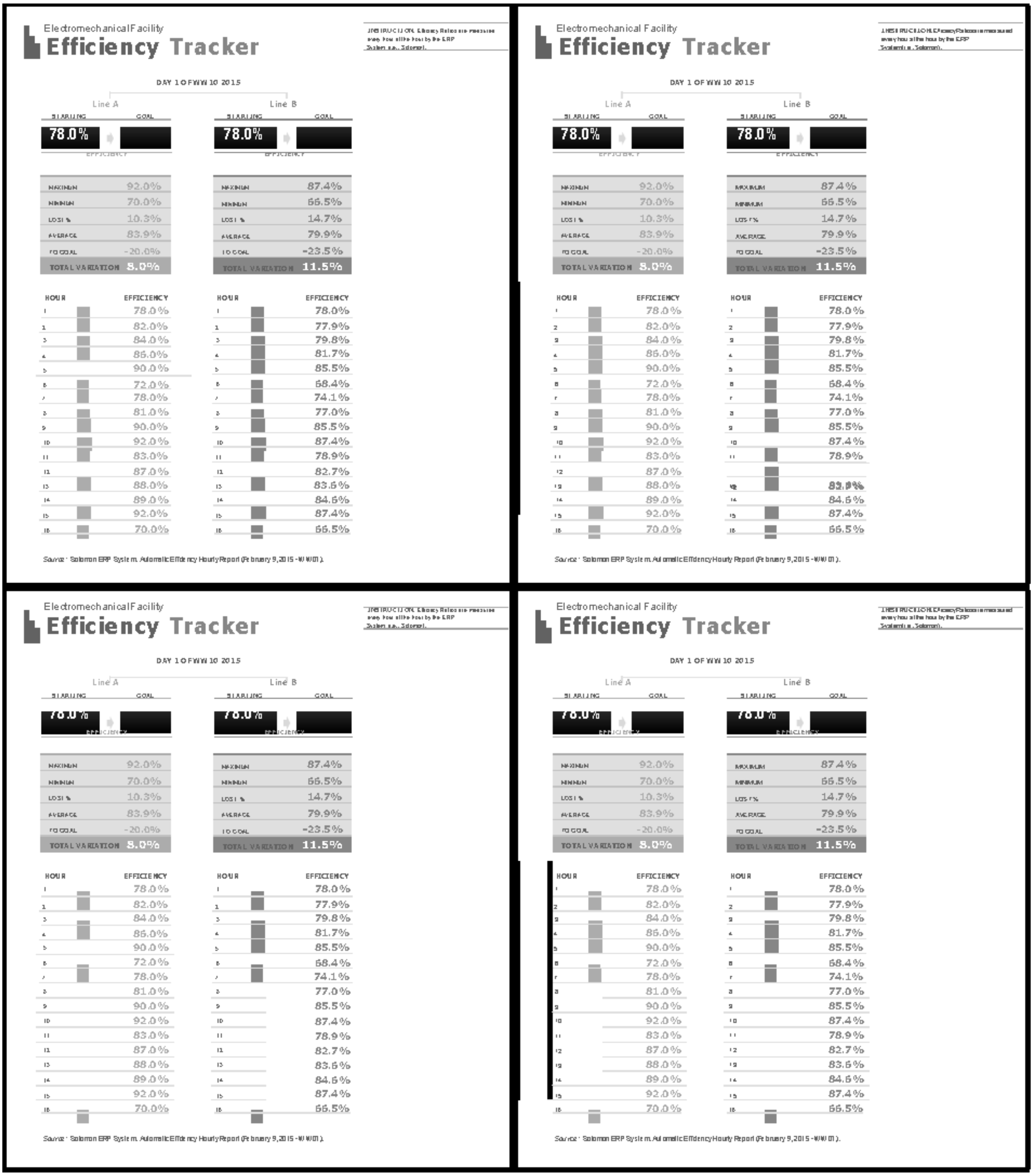

Figure 4: ERP Efficiency Report (Instrument of the Study). This is the instrument designed to measure the DV. This report is created by the ERP system of the Factory (i.e., Solomon). The report contains the efficiency ratios calculated by line every hour in the hour. One can download the efficiency ratios per day, per line, per week.

Assembly lines exposed to *slow music* tempo (MS) will not produce fewer units (E) than those exposed to faster music tempo (MF)). The sample is random and means of efficiency ratios presented in the experimental lines (E1 and E2) are calculated and compared, hoping they are different enough to reject H10 and conclude the difference in efficiency ratios is not fortuitous (chance variation), instead, it is because of the direct effect of the IV (music tempo). Based on the results of the hypothesis testing (H10: μE1=μE2), next step is proceed making claims about population parameters. Following convention, the level of significance (alpha level) is defined at 0.05, this alpha level will limit to 5% or less the chances to reject H10 incorrectly. Further, only 5% of the time there is a relationship in the population when there is not a link between music tempo and efficiency ratios (Type I error).

Data will be input into the *Statistical Package for the Social Sciences* (SPSS by IBM) using the statistical test independent samples *t* test (sampling distribution). The study looks to achieve *t*-statistic values greater than +2.00 or less than -2.00, this values will allow claiming this is a rare event (i.e., sample statistic falls in the so-called, critical region), and consequently reject H10. Last, proceed calculating with SPSS the probability value (*p-value* –a magnitude between zero and one, the closer to zero the better as this demonstrates H10 is less likely to be true). This statistic value indicates the "proportion of the area in the sampling distribution that lies at or beyond the value of the test statistic value" [18]. In summary, to claim the finding from this hypothesis testing is *statistically significant* will come from getting a *p-value* smaller than or equal to the defined *alpha level* (0.05). If this is achieved, H10 will be rejected and H1A will be tentatively accepted (i.e., assembly lines exposed to *slow music* tempo (MS) will produce less units (E) than those exposed to faster music tempo (MF): H1A: μE1≠μE2). A *one-tailed test* will be used to test the hypotheses; this approach is appropriate to the purpose of this study as it provides more strength to detect the effect of music tempo to the efficiency. The likelihood to have effects in the untested direction is minimal and irrelevant, they are negligible and in no way irresponsible or unethical.

Validity, Reliability and Generalizability

According to Christensen et al. [18], there are four types of validity in quantitative research to assist the researcher to ensure accurate inferences produce empirical findings. The four validity types are *statistical conclusion validity*, *construct validity*, *internal validity*, and *external validity* [18]. Of the four types of validity, statistical conclusion validity seems to support this experimental research better. Statistical conclusion validity is used because the independent and dependent variables covary. Covary means "that with every variation in the IV, there is a corresponding change in the DV; that is, IV and DV are statistically related" [18]. Empirical findings will show this hypothesis to be factually based, and the data should be replicable. This quantitative experimental study aims to be systematic and logical; resulting in an efficient method for answering research questions, and permitting manipulating, and controlling of selected variables. The variables selected, the level of measurement and the statistical analysis to convert data accurately into numerical information are expected to yield findings mathematically supported making generalizability feasible. A study cannot be reliable if it is too difficult or indeed impossible, to replicate –redo under the same conditions and using the same variables [19]. This study aims to be reliable (based on the analysis of mathematics and statistical mechanics described in the precedent section) and allow the creation of a regression linear model that will produce continually similar or identical results each time it is used.

Threats to Validity and Mitigation Plan

The study will target to be experimentally valid with genuine data not been affected by subject's perception of author's actions/answers. It is a closed deterministic system in which independent, and dependent variables are known and included in the model. Using Edmonds et al. [20] *reference guide* to minimizing the threats to internal and external validity, Tables 8-10 portray the actions this study aims to apply to accomplish this objective as shown in Figure 5.

It is evident, IV is operationalized, music tempo is controlled using a metronome as shown in Figure 6, that ensures music tempo setup is accurate. Researcher will use these devices (decibel meter, and metronome) to keep IV in control, measurement of volume, and music tempo will be collected and reported as part of the results of the experiment. Similarly, the instrument used to measure the DV is used extensively as supported in the literature [11,21,22]. It does not seem necessary to validate the instrument statistically.

Research Methodological Rigor

Methodological Rigor depends on designing and conducting the study with fidelity to the research design, from conception through reporting results [23]. This study aims to reveal that using experimental quantitative research provided useful inferences analyzing manufacturing plants setting (music tempo played on the production floor) and efficiency ratios. The study's results could be used to predict accurately the level of efficiency in assembly factories (repetitive jobs), allowing precise comparisons between assembly plants inferring similar results. Further support for this claim comes from the relevant conjecture about how MO can change the arrangement of their production areas – in this case, music settings to have a direct repercussion in their efficiency measures. Study's key assumption is that MO have the possibility and because of the use of resources, the

Threat	Action to Minimize the Threat
History	During the execution of the five phases of the experiment, there is not expected the occurrence of any assignable event during the time of the treatment that may alter subjects condition (e.g., change in job, death in the family, illness, or moving).
Maturation	Considering the DV is systematically calculated through the ERP system, there is not any natural process of changing, growing, or learning that may affect the results of the study as shown in Figure 4. Besides, the experiment is conducted in four weeks, from WW10 to WW14, allowing the researcher to identify any extraneous variable quickly and treat it.
Testing	Test is done with the subjects performing their work, in their regular workstations, following their standard work instructions, process flows, and process controls. Furthermore, a Solomon Four-Group design is developed to minimize the Pre-test sensitization issue derived from the subjects' awareness of the experiment and expected results after the change of the IV. Experiment is conducted in normal conditions, and subjects are not informed of it. Music will be played using existing sound system at the plant (quadraphonic surround) where volume level is the same in any operators' position on the floor as shown in Figure 1.
Instrumentation	Instrument of this experiment is the report of efficiency produced by the ERP system of the factory as shown in Figure 4. There are not expected changes on this system during the length of the experiment.

Note: Five phases of the experiment are complete from WW10 to WW14.

Table 8: Minimizing Internal Validity Threats.

Threat	Action to Minimize the Threat
Sample Characteristics	The cluster sampling procedure followed in this study is found appropriate and relevant for the purpose of the research. Above all, variation ratio between population and sampling is marginal; sample seems to have very similar characteristics to the population they belong (see Table 2).
Stimulus characteristics and settings	Considering the IV is playing music on the floor, one could expect different reactions from the subjects (e.g., surprise, relaxation, less talking between operators, less or higher quality, etc.). Nevertheless, this experiment aims to contribute quantifying these reactions in a comprehensive DV, efficiency, number of units (shippable product) per hour. Subjects' responses will be measured systematically with this metric replicating contrived laboratory conditions to real-life scenarios.
Treatment Variations	This experimental study uses ordinal and ratio measurement levels. IV, music tempo, is measured at an ordinal level when it is classified in two categories slow (MS: music tempo below 120 bpm), and fast (MF: music tempo above 120 bpm). IV is controlled by a very strict technique; volume is regulated using a decibel meter calibrated and accurate as shown in Figure 5.
Outcome Variations	Treatment is concrete and adequately controlled, and the probability to observe the effect of one type of outcome differing when alternate outcomes are seen is minimal.
Context- Dependent Mediation	The existence of mediating variables is controlled, and any potential inference in the efficiency can not only be identified timely during the treatment, but statistically measured and analyzed prior achieving definitive conclusions of this study.

Note: This is the strategy to maximize research validity. Through the execution of the five phases experiment obtain valid results. The sequence of actions described above is followed strictly by the researcher and it is evinced by the tables and figures reported.

Table 9: Minimizing External Validity Threats.

Threat	Action to Minimize the Threat
Attention and Contact with Participants	Experiment design is done in a way; researcher does not have direct interaction with the subjects. IV is varied by only playing different music tempo on the assembly lines and measuring the DV (efficiency). The intervention effect is minimized; experimenter will install two decibel sound meters as shown in Figure 5 to control the level of volume across the manufacturing floor, ensuring it is the same at all time. Measurements will be taken in two moments per work shift (morning shift at 6:00AM, and at 2:00PM; evening shift at 4:00PM, and at 10:00PM).
Single Operations and Narrow Stimulus Sampling	Similar to the attention and contact with participants, researcher has no direct effect on subjects, in fact, subjects will be exposed just to a new setup, music played during their work schedule. The probability to have the researcher delivering treatments differently based on experiences and expertise is null.
Experimenter Expectancies	Researcher' bias is also minimized as his expectancies, beliefs, and personal interests about the results are controlled as he will not interact with the subject, IV will vary by directly programming the music tempo and measuring the DV with the ERP system.

Note: This is the strategy to maximize research validity. Through the execution of the five phases experiment obtain valid results. The sequence of actions described above is followed strictly by the researcher and it is evinced by the tables and figures reported.

Table 10: Minimizing Construct Validity Threats.

Figure 5: Professional Decibel Sound Meter SPL-8810 used by the experimenter to ensure volume level is the same across the manufacturing floor. Two devices will be installed in strategic locations (shown in Figure 1) to control volume levels providing it is the same at all time.

Figure 6: Professional Digital Metronome portable 24-beats digital metronome used by the experimenter to ensure programmed music follows the specifications of M_S (music tempo below 120 bpm) and M_F (music tempo above 120 bpm).

responsibility to help humanity improving their quality of life, and this simple element, *music tempo* in production floors, could increase its efficiency having a direct enhancement of their productivity which is highly related to MO ability to remain competitive [2]. Table 11 depicts a summary of how each variable is measured and analyzed for which population, and with what instrumentation.

The validity of the inference about whether the IV and the DV covary will be documented in the results section, demonstrating statistical conclusions are valid (i.e., with every variation in the IV, there is a corresponding change in the DV, for that, a significance testing procedure is applied as described in the *Logic of Hypotheses Testing* section). Similarly, executing the threats minimization actions (Tables 8-10), internal (e.g., validity of the interference that the IV and DV are causally related), and external (i.e., validity of the inference about whether the causal relationship holds over people, settings, treatment variables, measurement variables, and time) validity are optimized. The number of participants is sufficient to minimize threaten statistical conclusion validity. In summary, this quantitative experimental research aims to be reliable and valid, ensuring scores and measurements are consistent with the rigor of its operational

Population	Sample	Type of Variable	Variable Name	Level of Measurement	Instrument	Remarks
Accessible Population: Electromec hanical Assembly Manufactu ring Plant (as a representat ion of Multinatio nal Organizati on (MO))	Drawn from the accessible population: Cluster Probability Sampling Procedure. Four Assembly Lines with 30 randomly selected operators as shown in Figure 1.	IV	Music Tempo	Ordinal	Professional portable 24- beats digital metronome.	It is classified in two categories slow (MS: music tempo below 120 bpm), and fast (MF: music tempo above 120 bpm). To ensure music sound is equally distributed throughout the manufacturing floor, a professional and self-calibrated sound meter is used (SPL-8810), volume level is controlled accurately.
		DV	Efficiency	Ratio	Efficiency report automatically produced by the ERP system of the manufacturin g plant as shown in Figure 4.	The absolute zero is the efficiency of units produced under current conditions (MO) in an hour period– zero means the absolutely no amount of whatever the variable indicates [7].

Note: Sample error is present but is random. It does not seem to follow a systematic pattern, an indication of an attributable factor (other than the variation of the IV). When error is random, the average of all possible samples is equal to the actual population parameter, and the values of the samples vary randomly around the true parameter [24].

Table 11: Methodological Rigor of the Study.

definitions. Again, the accuracy of the inferences made from the results is high, probing the study is measuring exactly what the researcher wants to quantity. Indeed, threats to validity are minimized with the use of proper control procedures. Among some others, confounding variables are acknowledged and its potential inference can be easily identify in the respective phases of the experiment, and using the instruments and statistical tools to quantify separately, reducing the risk of contaminating the interpretation of the cause-effect relationship between IV and DV. Sampling size seems representative, four assembly lines with 30 randomly selected operators, distributed in two work shifts. A Solomon four-group design is used to enhance both internal and external validity, this also resolves the *pretest sensitization* issue derived from the subjects' awareness of the experiment and expected results after the change of the IV. Above all, Solomon four-group design will resolve the internal validity threats (e.g., history, maturation, testing, instrumentation, regression, selection, mortality, and interaction of selection and maturation), and will minimize those for external validity (e.g., interaction of testing and X) as shown in Appendix B.

In like fashion, the types of statistical analyzes and the approach to generate results seems strong too. DV is measured for three consecutive weeks (from Monday to Friday, minimizing seasonal issues, and extraneous variables) using plant's ERP data (free of human dependency totally). This strength is paired with (1) the absence of experimenter presence as the control of the DV is made automatically, by simply changing the music tempo (this is considered a single- blind procedure, participants are not aware of the neither the experiment nor the planning results); and (2) the number of observations the experiment will produce (e.g., 240 per assembly line). This figure is found sufficient to apply the described statistics, comparison of means between shifts, and then between assembly lines, allowing the identification of changes in the DV not attributable to the IV (e.g., idiosyncrasy and behaviors by shifts, operators working at night, are usually slower than those working in the morning, or vice versa). In addition, variance analysis is done using one-sample *t-tests* with a confidence interval percentage of 95%, which will let estimating the probability of the underlying phenomena (music tempo effects on assembly lines efficiency). In other words, quantifying the change in efficiency with slower music (MS), and conversely, the change in efficiency with faster music (MF), this calculation will let define if they were indeed different. On the other hand, data distribution will be analyzed using both, *Skewness*, and *Kurtosis* distributions; standard errors for both distributions will be calculated to validate its level of representation of the universe (these statistical treatment is explained fully in the *Types of Statistics used to analyze the Data and Generate Results* section).

Last, it is acknowledged the existence of the imminent threat of using the achieved results in other groups (MOs). The limitation of generalizing the conclusions of this investigation is known, but it is minimized through the methodological rigor applied in the study. Indeed, this research aims to be reliable and comprehensive by disclosing transparently the phases and characteristics of the experiment design (i.e., easiness to understand sampling design, level of measurement of the variables, instruments used, descriptive and inferential statistical analysis, etc.) increases both, reliability and validity. MO in the *electronic manufacturing* and *original design manufacturing* industry (EMS and ODM respectively), can leverage the results of this investigation by assessing directly the similarity of the level of noise (music tempo) in their physical condition and apply the conclusions of this study. The rest of the infrastructural variables (e.g., temperature, humidity, lighting, and air quality) must be evaluated separately. One could consider this as a limitation, however these factors while important, are mostly controlled by the quality system of the MO, without them, the financial viability of such MO will be exposed [13].

Results of Hypothesis Testing

To ensure the statistical analysis was robust and healthy, and considering this was a *between-participants* experimental research, posttest-only control group (two groups, C1, and C2) was defined, and independent samples of *t*-test and one-way ANOVA were calculated, these calculations were followed by pretest-posttest control group (E1, E2, C1, and C2 respectively), where one-way ANCOVA calculation was complete too as given in Appendix D to I. The use of pretest scores helped to reduce error variance, thus producing more powerful tests [7]. By power test, one means the probability of detecting differences between the groups compared when such differences exist. Participants in the study were four assembly lines with 30 workers each. Music was played through strategically placed speakers that guaranteed the uniform distribution of sound as shown in Figure 1. Participants listened the music while working as they usually do in the eight hours work schedule. Efficiency was calculated automatically thru the ERP system of the factory; this system ensures data is taken objectively, with no influence or subjectivism on data gathering. Efficiency was measured every hour, this is, the number of units produced during that hour. These measurements were downloaded from the ERP in an Excel file, and then exported to the SPSS statistical tool to conduct the descriptive and inferential statistical analysis described above.

This quantitative experimental study examined how music tempos (slow and fast) could change the speed of motor activity increasing the number of units produced by standard electromechanical assembly lines while controlling for confounding factors. The following research questions guided the study:

- How music tempo affects the efficiency of line operators to produce electromechanical assemblies?
- Will the absence of music elicit higher efficiency ratios than those obtained when playing slow music tempo?
- Will the efficiency variance continuously change?

On the other hand, these three null hypotheses were tested:

H10: Assembly lines exposed to *slow music* tempo (MS) will not produce fewer units (E) than those exposed to faster music tempo (MF).

H10: $\mu E1=\mu E2 \rightarrow$ Rejected

H1A: Assembly lines exposed to *slow music* tempo (MS) will produce fewer units (E) than those exposed to faster music tempo (MF)

H1A: $\mu E1 \neq \mu E2$

H20: Assembly lines exposed to *white noise* (MO) will not produce more units (E) than those exposed to slow music tempo (MS).

H20: $\mu C1=\mu C2 \rightarrow$ Rejected

H2A: Assembly lines exposed to *white noise* (MO) will produce more units (E) than those exposed to slow music tempo (MS).

H2A: $\mu C1 \neq \mu C2$

H30: Assembly lines exposed to fast music tempo (MF) will keep the number of units produced (E) equal or smaller throughout the work shift.

H30: $\sigma E1 \leq \sigma E2 \rightarrow$ Rejected

H3A: Assembly lines exposed to fast music tempo (MF) will keep the number of units produced (E) higher throughout the work shift.

H3A: $\sigma E1>\sigma E2$

Through null hypothesis significance testing (NHST), this research invalidated H10, H20, and H30 and concluded there is a quantifiable causal relationship between music tempo (IV) and efficiency (DV). The objective to demonstrate (1) the slower music tempo is, the lower efficiency ratio the assembly line will attain, (2) white noise increases efficiency ratios, and (3) efficiency ratios continues changing with fast music, this is, efficiency will continue varying as music tempo gets faster, were all confirmed.

Discussion of the Findings

Data editing was performed prior to formal statistical analysis, using *check points* (e.g., range, consistency) to ensure data accuracy, characterize the mathematical attributes of each variable, define of statistical hypothesis tests (i.e., significance tests), determine confidence interval, and review the Type I error, Type II error, statistical power, statistical precision, and the relationship among these concepts and sample size. Major objectives of the analysis included, (1) evaluation and improvement of data quality, (2) deep description of the study population and its relationship to in-scope potential subjects, (3) assessed potential bias (e.g., attrition, comparison groups, nonresponse), (4) estimated measures of frequency and extent (e.g., prevalence, incidence, means, and medians), (5) estimated measures of strength of association or effect (DV, efficiency), (6) assessed the degree of uncertainty from random noise, (7) controlled and examined effects of other relevant factors (if any), (8) provided further insight into the relationships observed in the study, and (9) evaluated impact or importance.

Data Editing

Procedures, instruments, and forms are designed and pretested to maximize accuracy. Data collection activities were monitored to ensure adherence to the data collection protocol and to prompt actions to minimize and resolve missing and questionable data. The objective is to resolve satisfactorily data quality throughout the study. As indicated in previous sections, DV was measured using the ERP system – this report contains the efficiency ratios calculated by line every hour in the hour. One can download the efficiency ratios per day, per line, per week as shown in Figure 4. Data cleansing was done using these reports, basic data structuring techniques (e.g., range checks, data batching, grouping) to avoid loss of data or misinterpretation of observations. Further, this cleaning process allowed identifying outliers (even if correct their presence may have a bearing on which statistical methods to use) with attributable cause(s) –not part of the scope of this study. Range checks compared each data item to the set of usual and permissible values (e.g., efficiency rations between 75% and 85%, which are typical values in the current setup of the manufacturing site).Similarly, unusual values will be identified and investigated, and finally, verify reasonableness of distributions as they will affect also the choice of statistical procedures [25]. Similarly, consistency checks were applied too to examine impermissible combinations, unusual combinations, presence of denominators, missing or not applicable values, and the reasonableness of joint distributions (e.g., scatterplots, cross classifications, etc.). The likelihood to have these effects was limited yet the study aimed to support this with reliable data, as the DV was measured automatically with zero influence from the researcher. Data were downloaded from the ERP system to excel spreadsheets and the researcher maintained full control of the data entry process ensuring it remains accurate, reducing keying errors and data integrity issues derived from wrong data handling.

Analytic Techniques

Constructs or factors study are represented by variables [14]. This experimental study used ordinal and ratio measurement levels. IV, music tempo, was measured at an *ordinal level* (discrete variable) when it is classified in two categories slow (MS: music tempo below 120 bpm), and fast (MF: music tempo above 120 bpm). In the same vein, DV was measured at a *ratio level* (continuous variable) when it correlated the number of pieces produced (finished goods) per assembly line per unit of time (hour) using a ratio. As stated in the *Levels of Measurement of the Variables* section, there was a non-arbitrary zero point for the DV, so it is meaningful to characterize a value as x times the mean value, it is acknowledge any transformation other than multiplying by a constant (e.g., change of units) will distort the relationships of the values of a variable measured on the ratio scale [7].

Analytic techniques in this study was driven by seven principles, (1) simpler is better, (2) avoid extraneous detail, (3) never overwrite data, instead, create additional variables as applicable, (4) inspect detail before relying on executive summaries, (5) confirm accuracy of derived variables by examining cross-tabulations between original and derived variables, (6) identify and calculate any thresholds effects, presence of saturation phenomena, and other nonlinearities, and (7) categorize based on the nature of the phenomenon, in this case, productivity enhancement in manufacturing factories as a result of the use of music tempo. To get a feel of the data, distribution of each variable was inspected as given in Appendixes D to I. Through the use of SPSS, researcher observed data distribution shape (comparting symmetry *vs.* Skewness) and identify data discontinuities, relationships in data, important subgroups, and proportion of missing values (location and dispersion statistics will be used for such purpose – mean, median, percentage above a cut-point for the former, and standard deviation and quantiles for the last).

Descriptive Analyses

Exploration of data becomes a descriptive analysis [18]. Consequently, this study aimed to examine and report measures of frequency (incidence, prevalence) and extent (means, survival time), association (differences and ratios), and impact (attributable fraction, preventive fraction) between DV and IV. These measures were computed for the selected sample, based on the characteristics of the population and the strictness of the experiment design, standardization or other adjustment procedures may not be required for differences in the subjects' demographics or other risks factor distributions (e.g., subjects' emotions, seasonality, or any other extraneous influences). Similarly, the assessment of the hypothesis testing of the likely influence of random variability on the data was minimal or absent entirely, again, assertions based on the design of the experiment and the sequence of its implementation as shown in Figure 2 and Tables 3-7.

Evaluating the role of chance (interference): The over-reliance on statistical tests weakness researchers' capacity to interpret data and to take a reasonable decision to infer results in the population accurately [14]. Further, test of significance are probably the most common procedures for assessing the role of chance, more specifically, the amount of numerical evidence that observed differences would not readily arise by chance alone [20]. In a related vein, statistical test of significance defined as "device for evaluating the amount of numerical data on which an observed pattern is based" [12], was used to evaluate the strength of numerical evidence for discounting chance as a likely sufficient explanation of the DV effects when manipulating deliberately the IV (music tempo) in the factory.

Statistical power and sample size: Statistical power refers to the ability to detect an association of interest in the face of sampling error [25]. Based on the results of this study as given in Appendix C, there is a true association of a certain type and degree between music tempo and efficiency ratios in manufacturing factories. Sampling error was contained efficiently as sample size (i.e., the number of subjects) was sufficient enough that (1) the expectation of observing the association is high and hence, minimizing the risk of making a Type II error (fail to reject H0, concluding mistakenly that data are consistent with the model), and (2) it is unlikely that chance could produce an association of this size. The intolerance for error (i.e., small alpha and beta values) and desire to detect weak associations is compensated truthfully with sample size. The study´ results appear to be accurate and representative enough of the population consenting generalizability as shown in Appendixes D through I.

Conclusion

The suggestion that music tempo could increase the pace of movement of line workers to produce higher production rates (efficiency) seems feasible as movement speed can be changed through cognitive stimuli [26]. Literature is vast showing music tempo correlates positively with people' perception of speed change [27]. Because mental states change speed [28], and music tempo creates mental states, this study quantify proficiently the effect of music tempo on manufacturing efficiency ratios of mechanical assembly factories, considering that physical speed of workers on the assembly line could be altered by music. Indeed, this experimental research measured accurately the change in units produced per hour varying the music tempo. Through a relevant and pragmatic experiment design, this quantitative research depicted a strong alignment between purpose, research questions, test hypotheses, and results. Problem statement delineated clearly the problem (MO´s productivity ratios immersed in today's´ hyper-competitive economy), the purpose statement (e.g., understand if there is a causal relationship between the music tempo played in a manufacturing facility (IV), and its level of efficiency (DV) measured as the number of products assembled per unit of time) flows from the problem statement. Research questions that directed the central inquire of the study, aligned smoothly with the problem and purpose statements (e.g., (1) How music tempo affects the efficiency of line operators to produce electromechanical assemblies? (2) Will the absence of music elicit higher efficiency ratios than those obtained when playing slow music tempo?, and (3) Will the efficiency variance continuously change?). Through null hypothesis significance testing (NHST), this research invalidated null hypotheses (H10, H20, and H30) and concluded there is a *quantifiable causal relationship* between music tempo (IV) and efficiency (DV). The objective to demonstrate (1) the slower music tempo is, the lower efficiency ratio the assembly line will attain, (2) white noise increases efficiency ratios, and (3) efficiency ratios continues changing with fast music, this is, efficiency will continue varying as music tempo gets faster, were all confirmed. The hypotheses crafted provided testable statements, relevant to the purpose of the study and linked directly to the problem statement; the research remains intently and narrowly focused on addressing the topic providing reliable quantifiable evidence that future researches could use to expand this field of knowledge, critical to the continuous success of MO.

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