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Application of Single-Case Research Designs in Undergraduate Student Reports: An Example from Wellbeing Science

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Abstract

Introduction

Psychological science is undergoing a period of change and transformation.

Statement of the Problem

The crisis in confidence over psychological science has led to an emphasis on larger and larger sample sizes, sustaining an unfortunate neglect of single-subject research designs in undergraduate education.

Literature review

We identified several excellent articles advocating for the benefits of single-subject and small *N* designs over group-based research designs, yet single-case designs are seldom taught at undergraduate level.

Teaching Implications

Teachers of psychology are provided with resources for implementing training in single case research designs at undergraduate level, enabling students to draw objective conclusions in an *N*-of-1 research report. We do this using an example from a recently developed module on wellbeing science.

Conclusion

Embedding an underused methodological approach for determining objective change in single individuals into undergraduate psychology curricula will help to develop practical skills applicable to many roles in the discipline of psychology, the healthcare sector and the quantified-self community.

Keywords

statistical process control analysis, single-case report writing, self-assessment, self-reflection, student-focused learning, GENIAL model

While psychology has a long history of adopting single case research designs (SCRDs; Boring, 1929; Morgan & Morgan, 2001), recent developments in the field have led students to question the validity of single-case methods. We have even observed students to declare that 'a small sample size' is a major limitation of their work, and that "in future, researchers should consider including a larger sample size to test predictions". There are many potential reasons why students question the validity of SCRDs. One reason is the crisis of confidence in psychological science (Pashler & Wagenmakers, 2012; Sarafoglou et al., 2020; Simmons et al., 2011), which has important implications for teaching psychological science. This crisis has led to calls for lowering the criterion for statistical significance from $p < 0.05$ to $p < 0.005$ (Benjamin et al., 2018), which would require a 70% increase in the sample size to achieve 80% power (Lakens et al., 2018; Smith & Little, 2018). Another reason is reference to hierarchies of evidence (Murad et al., 2016), which present the randomised controlled trial (RCT) as the gold standard, while single-subject designs are characterised as methodologically weaker. Students are often surprised to learn about the considerable benefits of SCRDs (Table 1), which is ironic considering those same students often would like to establish a career in clinical psychology and related fields. It is helpful to know that a certain technique or intervention is supported by RCTs, but it is also important to know whether that particular approach is helpful for an individual in the real world. This is the aim of SCRDs and the focus of the current paper.

Table 1

Benefits of single-case research designs (SCRDs) and comparison with group-based research designs (GBRDs)

Benefits of rigorous SCRDs	Point-by-point comparison
1. *Specificity:* Able to determine whether particular interventions have an objective impact on a single individual.	GBRD findings are limited to group averages and do not allow for conclusions to be drawn for any particular individual.

2. *Clarity:* Provide clarity for determining change in single individuals, an objective relevant to the 'quantified-self' community, psychologists, and clinicians. Meaningful effects are typically noticeable on visual inspection.	Clinical conditions and / or targeted interventions limit the applicability of GBRDs. Individuals often have different needs and specific goals. GBRDS mask individual differences.
3. *Simplicity:* Able to be carried out in resource-constrained settings with minimal funding.	GBRDs typically require significant funding, time and resources.
4. *Internal validity:* Provide strong internal validity based on repeatedly sampling the dependent measure leading to a representative sample of performance or behaviour.	GBRDs seldom involve repeatedly sampling data under identical conditions. This approach is seldom practical. Unfortunately, the lack of repeated sampling in GBRDs limits internal validity.
5. *External validity:* Provide strong external validity by moving from the single case to larger samples of cases, allowing relevant controlling conditions to be identified prior to establishing generality.	Performance of the group does not predict the performance of an individual, except in a probabilistic way.
6. *Control:* Provide enhanced control of potentially confounding variables as each participant serves as their own control.	GBRDs are associated with observed and unobserved confounding, often addressed in inappropriate ways (e.g. ANCOVA on participants not randomly allocated to group).

We were especially interested to read the article published in the Teaching of Psychology journal (Morgan, 2009), which described the application of statistical process control (SPC) analysis in undergraduate curricula. Interested readers are referred to several other excellent articles (Callahan & Barisa, 2005; Morgan & Morgan, 2001; Normand, 2016; Smith & Little, 2018) advocating for the benefits of single-subject or small *N* designs over group-based research designs (GBRDs). We also acknowledge a sizable literature on this topic in the behavioural and health sciences, especially in the field of rehabilitation (e.g., Callahan & Barisa, 2005; Pfadt & Wheeler, 1995) . Unfortunately, SCRDs are seldom taught at undergraduate level, motivating us to implement this approach into an undergraduate psychology third-year module on wellbeing and describe how we have done this in the present paper. This approach also helps to facilitate an evidence-based approach to living.

Context

The teaching of single case research designs is integrated into a recently developed module on wellbeing science, based on our recently developed theoretical foundations and reviews of the literature (Kemp et al., 2018; Mead et al., 2019, 2021). The module is structured around five broad interconnected components known to influence and sustain wellbeing including connection to self, connection to others, connection to nature, social contextual factors and positive change, and is delivered over a five-week period (Table 2). This approach is consistent with second- and third-wave positive psychology (Kern et al., 2019; Lomas et al., 2020; Wong, 2019) and is inspired by and complementary to multi-levelled social ecological theory (Bronfenbrenner, 1977; Lomas, 2015). The first week of the module provides students with background information and theory, after which students are introduced to a variety of interventions relevant to the focus of weeks two to five (Kemp & Fisher, 2021b). Readers interested in learning more about the wellbeing module itself are referred to the following sources (Kemp et al., 2021; Mead et al., 2021).

Table 2

A summary of content and activities across the 5-week module on wellbeing science.

Week	Focus of session	Session summary	Structure and activities[†]
1	Introduction & theoretical framing	Wellbeing is defined from a biopsychosocial perspective in the context of major societal challenges including for example, societal loneliness, increasing burden of chronic disease and anthropogenic climate change.	Comprises seminar, online learning module and quiz. Students identify their dependent variable and begin data collection for report. Data collection during week 1.
2	Connecting to self (the individual domain)	Capacity for individual positive change is highlighted with focus on a 'balanced mind' and 'healthy bodies'. The vagus nerve is introduced as a structural link between mental and physical health.	Comprises seminar, online learning module and quiz. Students complete the VIA character strengths survey and reflect on how strengths may contribute to improving wellbeing. Data collection from week 2 is associated with the beginning of the intervention period. Positive psychological interventions and health behaviours are introduced.
3	Connecting to others (the community domain)	Social identity and opportunities to connect to others are discussed (e.g. volunteering). Students are also introduced to sociostructural and contextual factors such as	Comprises seminar, online learning module and quiz. Data collection ongoing. Students complete a values clarification questionnaire and reflect on associations with happiness. Students

		inequality and culture, which have important impacts on wellbeing but lie beyond the control of the individual.	select an additional intervention relevant to the community domain.
4	Connecting to nature (the environment domain)	This session highlights the relationship between a nature connectedness and wellbeing. The relationship between positive psychology, pro-environmental behaviours and environmental sustainability is discussed.	Comprises seminar, online learning module and quiz. Data collection ongoing. Students select an additional intervention relevant to the environment domain.
5	Positive behaviour change	This section focuses on goal setting and sustained positive change. Emphasis is placed on the vast capacity for individual change, despite sociostructural impediments. The potential for societal transformation through psychological boosting and wellbeing public policy, is also discussed.	Comprises seminar, online learning module and quiz. This week represents final week of intervention period. Students are encouraged to reflect on how they might sustain positive changes made. Data collection continues beyond the end of the module, a period lasting up to 2-weeks, representing the follow-up period.

Collecting Data

Students are informed in the module handbook that the assessment involves writing-up a single-case report on themselves ($N = 1$) and involves analysis of repeatedly sampled data across baseline, intervention and follow-up conditions. Students will not be accustomed to repeated sampling of data, nor will they be familiar with writing up a report on a single

case. As our module is focused on wellbeing science, the dependent variable (DV) collected by students included a focus on relevant and associated constructs such as happiness (Lyubomirsky & Lepper, 1999), flourishing (Diener et al., 2009), wellbeing (Lambert et al., 2020) or heart rate variability (Kemp et al., 2017a, 2017b; Quintana et al., 2012). It is important for instructors to encourage students to begin collecting data as soon as possible. While most students begin collecting data in week 1 during which an introduction and contextual information is provided, ambitious students may begin collecting baseline data 1-week prior to the commencement of the module, allowing those students to have 2-weeks' worth of baseline data.

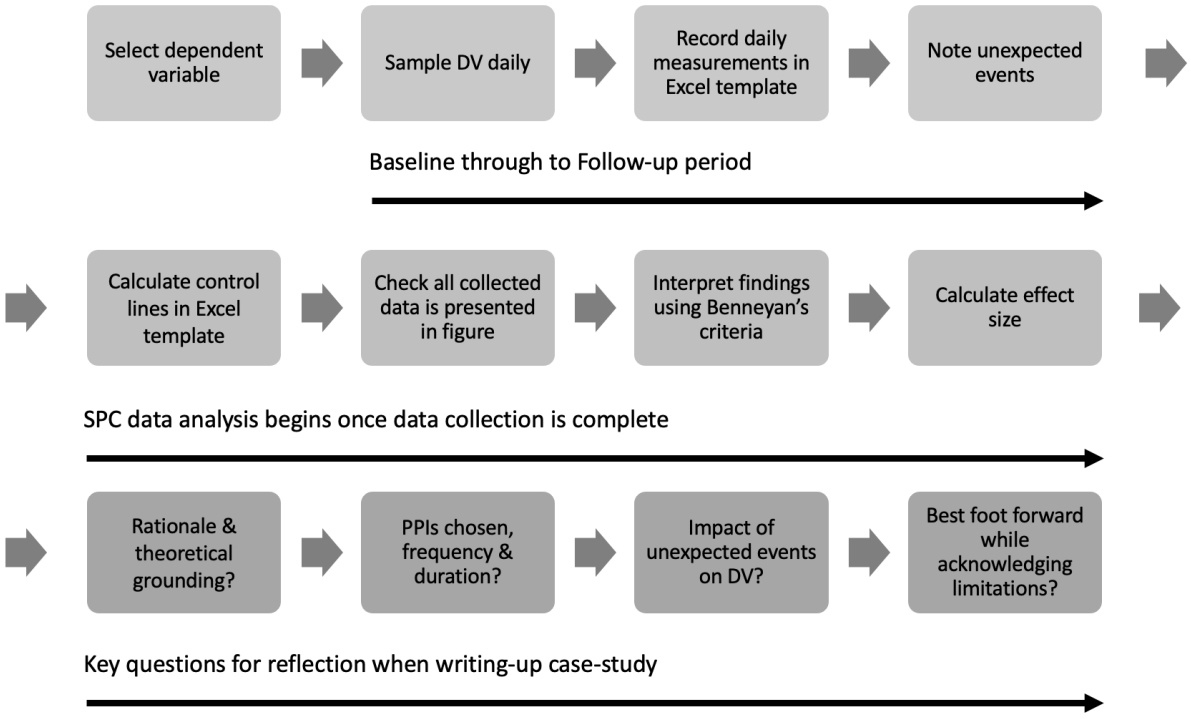
Researchers have recommended as few as 5-datapoints for each study phase (Kratochwill & Levin, 2014; Lobo et al., 2017), although others (Callahan & Barisa, 2005) have recommended between 12- to 15-datapoints to ensure reliability. More data will allow students to better account for daily fluctuations in their DV on which various thresholds will be determined. Students begin collecting data on their chosen DV up to two weeks prior to commencing the intervention in week 2 of the intervention period. Data collection takes place daily, throughout the baseline (up to 2-weeks), intervention (4 to 5-weeks; note that the intervention is introduced from the second week of the module, so students have some flexibility around the amount of data collected during baseline and intervention phases) and follow-up (up to 2-weeks) periods. It is important therefore that students are clear about what they have done when writing up the methods section of their report.

Students record each daily measurement in the Excel template, provided in supplementary information (Kemp & Fisher, 2021c), and note any unexpected events – and the days on which these occurred – that may have impacted on their chosen DV. Such events include for example, an unexpected stressor, major life event or illness. Students are encouraged to reflect on the important distinction between the impacts of acute and chronic illness on their data. While both will impact on the DV, these factors will differ depending on the nature of the variable being considered. For instance, in the case of acute illness (e.g.,

seasonal flu), a temporary and time-dependent impact will likely be observed on the DV. By contrast, chronic illness including a mental or physical health condition may also impact on the DV, although this impact is unlikely to change across the different phases of the study (i.e., baseline, intervention, follow-up), assuming for example, that treatment does not change over the data collection period. While students are encouraged to provide sufficient context to allow sensible conclusions to be drawn, for reassurance, they are also informed that they do not need to share any information if uncomfortable in doing so. Once data collection is complete, students must apply SPC analysis to the recorded data, interpret their results and write-up their reports. Figure 1 presents a summary of the various steps that students follow to complete the module. In the next section, we describe how students might visualise and interpret collected data.

Figure 1

Key considerations for students



Analyzing Data

SPC analysis allows one to detect whether change following the intervention (i.e., special cause variation) has greater impact on the chosen DV relative to natural variability over time (i.e., common cause variation). The process of drawing objective conclusions from data collected is intuitive and provides students with a greater appreciation for data collection and the research process. Students also gain an understanding of the natural variability in the measured DV over time, a phenomenon that is typically ignored in GBRDs (Table 1). A key concept here is the '68 – 95 – 99.7 rule', which reflects a fundamental feature of Gaussian distributions (i.e., the normal, bell-shaped distribution), which indicates that 99.7% of baseline data will lie within 3 standard deviations of the mean. By calculating the upper control limit (UCL; 3 *SD*s above the mean) and lower control limit (LCL; 3 *SD*s below the mean) from the baseline phase, the majority of data (99.7%) should lie between UCL and LCL, assuming data are normally distributed. Data lying outside these limits are then interpreted as 'special cause variation', referring to variation that lies beyond expected daily fluctuations.

In fact, Benneyan's criteria (Benneyan et al., 2003) provide six criteria for determining whether or not special cause variation has arisen in student data. These criteria include the following:

1. points lying above or below 3 *SD* of baseline control limits;
2. two out of three successive points more than 2 *SD* from the baseline mean on the same side of the centre line;
3. four out of five successive points more than 1 *SD* from the mean on the same side of the centre line;
4. eight successive points on the same side of the centre line;
5. six successive points increasing or decreasing; and
6. any obvious cyclic behaviour in the plotted data.

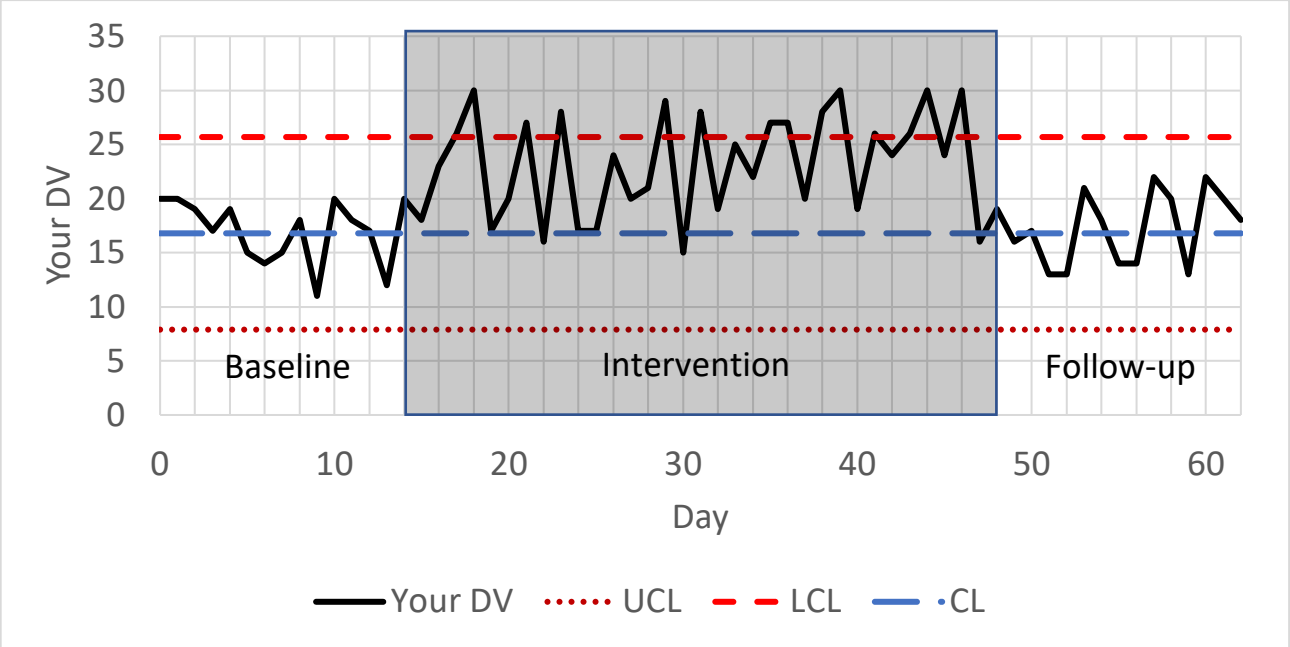
Students do not need to meet criteria for all six rules as they simply provide guiding questions to help students address their research question in a more objective and evidence-based way. If any of their answers to the six guiding questions are 'yes' they have then obtained (some) evidence for special cause variation. Helpfully, researchers have also described the process of determining whether special cause variation has arisen in the data using the mnemonic of "ones, runs and trends" (Callahan & Barisa, 2005), defined as follows:

1. 'Ones' are referred to as those points lying beyond the UCL and LCL.
2. 'Runs' are described as seven or more consecutive points lying above or below the control line.
3. 'Trends' are described as seven or more consecutive points moving up or down that bisect the control line.

The reporting of results is largely descriptive and focused on explaining what was found with the help of SPC analysis and corresponding visualisations of the data (e.g., Figure 2), rather than worrying about an arbitrary statistical significance threshold as is the case for traditional group-analysis. The focus should be on gathering the evidence to reasonably say that the intervention works or not. It is helpful to visualize data in a figure, such as figure 2. Once data collection is finalized, students can create a similar figure based on their own data and minimal editing of the Excel template provided in supplementary information (Kemp & Fisher, 2021c). Figure 2 visualizes repeatedly sampled hypothetical data relating to a chosen DV ('Your DV') across time ("Day") demarcated according to the three different study phases: baseline, intervention and follow-up. Visually presenting collected data in this way is standard practice in SCRDs and researchers suggest that meaningful effects of the independent variable should be noticeable from such presentation (Morgan & Morgan, 2001).

Figure 2

Example of figure with hypothetical data to summarize impact of intervention on a dependent variable relevant to wellbeing science.



Note: Your DV = the dependent variable (DV) relating to the chosen measure; UCL = Upper Control Limit (UCL), + 3 standard deviations (SDs) from the mean of the baseline condition; LCL = Lower Control Limit (LCL), - 3 SDs from the mean of the baseline condition; CL = Central Line, which is the average of 'Your DV' for baseline condition.

Instructors may also wish to encourage students to report a measure of effect size, consistent with APA guidelines. For simplicity, we recommend the standard mean difference (SMD) metric. This is calculated by determining the difference between the mean value of the intervention and baseline periods, and then dividing by the standard deviation of the baseline. This approach has been recommended previously (Olive & Smith, 2005), although, it is important to note that such measures are not comparable to commonly employed standardized thresholds (Cohen, 1988) for small (0.3), medium (0.5) and large (0.8) as these relate to thresholds for between-subject GBRDs. Instead, students may simply interpret their

effect size as a percentage of a standard deviation, such that a SMD of 1 would mean that the difference between conditions equals 1 full standard deviation above baseline. These effect sizes may also be of interest to instructors as they review and compare student reports. Prior publications on this topic have described how to produce effect sizes that are comparable to group designs (Shadish et al., 2013, 2014; Zelinsky & Shadish, 2016).

Writing the Report

Once data has been inspected and interpreted, as described in the preceding section, students must then write-up their reports for submission by the due date. Our student reports are comprised of no more than 2000-words, all-inclusive, except for the cover sheet and any appendices. This means that the abstract, introduction, methods, results, discussion, in-text citations, figure, table (if included), and references are all included in the 2000-word limit. While students may consider this word limit to be overly restrictive, instructors can use this requirement as a 'teachable moment' that can help alert students to similarly brief requirements for reports written in the workplace environment. Detailed guidance for students on writing up their reports including specific guidance over and above that provided in the APA Publication Manual is included in supplementary information (Kemp & Fisher, 2021a). This guidance includes a focus on how to write-up each section of the report including information on developing an informative title and abstract, building a strong rationale and integrating theory into the introduction section, writing up a methods section that adequately describes an underused technique in psychology, and reflections on developing a strong discussion section that helps the student put their 'best foot forward', especially in relation to the advantages of SCRDs (Table 1, Figure 1). We have also found that this guidance to be a helpful resource for markers of student reports, grade moderators and external examiners who may be unfamiliar with SCRDs and its application in undergraduate curricula.

Discussion

The discipline of psychology have typically neglected SCRDs in undergraduate curricula leading students to question their validity. We have even observed student reports to include a ‘small sample size’ as a limitation in the discussion section of their single-case reports. This highlights a need for a greater focus on the benefits of SCRDs (Table 1) as we describe here. A ‘small sample size’ is a feature of SCRDs, not a limitation. Rather than discussing the ‘small sample size', it would be more insightful for students to discuss the characteristics of the participant under investigation with respects to the wider literature.

Alongside the benefits of SCRDs, several limitations of the design described here are worth acknowledging. There are many different types of SCRDs (e.g., the AB design, the reversal design, and reversal design with crossover for multiple interventions), each with their own methodological strengths and limitations (Lobo et al., 2017). A limitation of the approach that we describe here (i.e., a variant of the AB design that includes a follow-up period) is possible carry-over effects that may arise when students continue their intervention into the follow-up period. In this situation, there may be no apparent change on the DV from the intervention to the follow-up period. This methodological limitation is countered by ethical considerations that relate to asking students to cease wellbeing-related interventions at the end of the 5-week module. It is also possible that the impact of the intervention continues beyond the intervention phase regardless of continued involvement. For instance, according to Fredrickson’s broaden-and-build model, positive emotions may leave a lasting legacy associated with the building of cognitive, psychological and social resources (Fredrickson, 2004).

Students should be encouraged to reflect on the frequency and time-period that they engaged with their chosen intervention, as these considerations will impact on the extent to which Benneyan’s criteria are met, and the extent to which the DV continues to display change during the follow-up – relative to baseline – period. Accordingly, there is much opportunity for reflection in the discussion section of student reports. Another limitation of

the described experimental design is the absence of randomisation of repeated conditions, which limits internal validity of reported results. For this reason, students are encouraged to reflect on events arising over the course of the study that may have potentially impacted on their chosen dependent measure when writing up their reports. These considerations also lend themselves to useful class discussions to help students understand the design logic of SCRDs, guided by discussion papers on this topic (e.g., Lobo et al., 2017).

In conclusion, this paper provides instructors with much-needed context and resources for teaching an underused technique to undergraduate psychology students. Supplementary information includes additional information to support this effort including a description of some of the wellbeing-focused interventions that our students chose during module delivery in the 2020/2021 academic year (Kemp & Fisher, 2021b), a template for recording repeatedly sampled data Kemp & Fisher, 2021c), which can then be used to create a figure for visualising collected data, and guidance on how to write up student reports (Kemp & Fisher, 2021c). Through application of an evidence-based approach for objectively determining the impact of an intervention on single individuals, students learn how to bridge the gap between research and evidence-based living. This approach provides students with the tools needed to evaluate outcomes in real world, professional and clinical settings.

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