Optimizing Behavioural Observations: A Comparative Approach to Simulated Sampling Methods

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Original Research paper

**Running title:** Comparison of behavioural recording methods

**Abstract:**

*Keywords:* continuous recording, pinpoint sampling, one-zero sampling, measuring behaviour

**INTRODUCTION**

The measurement of behaviour has become a major area of scientific study for those involved in the scientific study of animal behaviour. Behavioural studies are used as a tool to measure captive animal welfare, and are used more often than other welfare indicators such as glucocorticoid analysis (Fraser, 2009; Sands & Creel, 2004). For captive animals, behavioural research may also be used to investigate the prevalence of positive behaviors, such as foraging, or negative behaviors, such as stereotypies (Carlstead, Baldwin, & Seidensticker, 1991; Fernandez & Timberlake, 2008; Ward, Sherwen & Clark, 2018). Studies of behaviour are also frequently conducted for wild animal populations, to better understand natural history or investigate the impact of human disturbance (Lehner, 1998; Sand & Creel, 2004). Research on animal behaviour is now so well recognised that there are numerous journals dedicated to its study, for instance: *Animal Behaviour,* *Applied Animal Behaviour Science, and Ethology.*

The methods used in animal behavior research can be traced back to human studies. Scientists during the mid-twentieth Century often used a mixture of both human and animal models to answer questions in the field of behavioral psychology (Domjan, 2014; Pierce & Cheney, 2013). Based on the range of different techniques that were generated by earlier studies, Altmann (1974) summarised the behavioural research methods available. This paper became fundamentally important to those interested in behavioural research, and remains a keystone paper for researchers, with at least 16,100 citations, according to a search on Google Scholar (2020). Whilst other authors, such as Martin and Bateson (2007) further refined the behavioural methods and their definitions, Altmann’s work is still regularly cited.

Since this initial review of behavioural methods, some behavioural sampling techniques became increasingly popular in animal literature, whereas others are rarely used. Several behaviour measurement techniques have received some criticism in terms of their repeatability (Bernstein, 1991). For example, ad libitum (qualitative) sampling may be useful for developing ethograms and for pilot studies but has methodological flaws with regards to its lack of standardisation (Martin & Bateson, 2007; Rhine & Ender, 1983). However, ad libitum sampling is still used in animal behaviour literature, with a review by Mann (1999) identifying that between 53% and 59% of cetacean studies published in *Marine Mammal Science* used this sampling technique.

Continuous recording, or focal sampling, is considered the gold standard for behaviour sampling, as this method records all occurrences of behaviour and their durations (Hämäläinen et al., 2016). In the past, this made continuous recording challenging for researchers, as an active animal that rapidly changed behaviour would have been difficult to gather representative data for (Tyler, 1979). Similarly, the recording of multiple animals using a continuous method would have been incredibly challenging to record accurately, hence why the method is considered synonymous with focal sampling of one individual (Altmann, 1974; Martin & Bateson, 2007). Use of modern technology has in part ameliorated some of these issues by allowing behaviour to be recorded and analysed later (Amato et al., 2013). However, continuous recording may remain a challenge, even with camera availability. As a result, several sampling methods have been developed to measure multiple animals at one time (scan sampling), as well in a non-continuous fashion.

The use of pinpoint sampling, also referred to as instantaneous or momentary time sampling, is a commonly used method for observational study (Fernandez, Kinley & Timberlake, 2019; Stevens et al., 2013). With pinpoint sampling, one or more responses are recorded at preselected moments in time (e.g., every 15 s for an hour). The benefits of instantaneous sampling are that it is less intensive than continuous sampling, and therefore may be more feasible for researchers to conduct (Grenier et al., 1999; Martin & Bateson, 2007; Rhine & Flanigon, 1978). The methods are also more versatile, allowing researchers to make decisions as to how long intervals should be spaced. For example, some researchers might choose to use 15-second intervals, particularly when studying an active animal or when conducting observations of a key time period, such as when enrichment is provided (Fernandez & Timberlake, 2019). On the other hand, observers might choose to use much longer intervals, such as one, two or five minute intervals when their subjects are inactive or if they are observing for long time periods (Shora, Myhill & Brereton, 2020; Teixeira et al., 2017). It has been noted by some authors that shorter intervals tend to result in behavioural values that match more closely the continuous behaviour scores (Pullins et al., 2017).

One-zero or interval sampling involves choosing specific intervals of time, like pinpoint sampling, but instead recording whether one or more responses occur (or conversely, do not occur) within that interval of time (Bailey & Burch, 2017; Lehner, 1998). While popular with both human and non-human primate research, one-zero sampling seems to receive less representation than pinpoint sampling in most animal behavior studies and has been criticised in by previous researchers (Altmann, 1974; Rhine & Flanigon, 1978). However, one-zero sampling has some of the same benefits of instantaneous sampling, in that interval length can be tailored in line with the requirements of the study. Additionally, one-zero sampling has the potential to collect more behaviours during a stated period, as multiple behaviours can be recorded during each interval (Altmann, 1974). Leger (1977) identified good agreement with continuous behaviour measures when using one-zero sampling at 15-second intervals for chimpanzees (*Pan troglodytes)*. Likewise, Gilby, Pokempner, and Wrangham (2010) found similar levels of occurrence when comparing continuous and one-zero sampling methods for the foraging behavior of wild chimpanzees. As noted above, one-zero (interval) sampling is also frequently used in studies on human behaviour, for example in the classroom (Dunkerton, 1981; Omark et al., 1976).

Both pinpoint and one-zero sampling overcome some of the issues associated with continuous recording by reducing the amount of input required by the researcher, while still aiming to keep the sample representative of the animal’s behavioural repertoire (Mitlöhner et al., 2001; Simpson & Simpson, 1977). However, one key question is how closely these techniques correlate with continuous recording? Instantaneous sampling is reported to lose information in terms of behaviour duration and is potentially less likely to pick up any behaviours of short duration (events) (Martin & Bateson, 2007; Xiao et al., 2005). By contrast, one-zero sampling is better at recording all observable behaviours, but both behavioural frequency and duration could be easily misrepresented: there is no way to identify whether a behaviour recorded as present for one interval was seen once or thirty times during that time period (Saibaba et al., 1996).

The following study proposes to compare simulated occurrence of both low, medium, and high frequency/duration behaviours, as well as similar observation periods and for both pinpoint and one-zero sampling methods. We hypothesized two results: (1) pinpoint sampling would provide a more accurate representation of percentages of occurrence for both low, medium, and high duration behaviors than one-zero sampling, and (2)one-zero sampling would be better suited for detecting the occurrence of low frequency behaviors, particularly when comparing less frequent pinpoint and one-zero observation methods (e.g., 5 min observation periods).

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**METHODS**

For all simulations, continuous recording methods were generated for both frequency of occurrence and percentage of occurrence, with two different non-continuous sampling methods directly compared: pinpoint (instantaneous) and one-zero (interval) sampling. Independent variables were split into two categories: Response frequency (event) and response duration (state). Three levels for response frequency and response duration were determined, based on an arbitrarily level of occurrence: 3 s, 30 s, and 300 s. Simulated observations were similar set to 3 s, 30 s, and 300 s intervals during a one-hour observation period. Two separate simulations for both response frequency and response duration (the independent variables) as follows:

***Response frequency***

This simulation focused on the recording of event behaviours: behaviours of very short duration (Martin & Bateson, 2007). For the purpose of the simulation, the duration of all event behaviours was set to exactly one second. Next, three different frequencies of event behaviour were selected: these consisted of frequent (occurs every three seconds), moderate (occurs once every 30 seconds) and infrequent (occurs every 300 seconds). Simulated data was developed for each of the three behavioural frequencies. These simulated data sets were 1 hour in length (3600 seconds). A randomisation programme was used to select times for behaviours to be included in the simulation.

A continuous data set was developed by recording all behaviours and their durations from the simulated hour of data. The behaviours were then transformed into a percentage of total time (as is often shown in behaviour studies in the form of an activity budget), as well as frequency of occurrence.

Both pinpoint and one-zero sampling were then calculated to compare against the continuous, ‘gold-standard’ data set. Three observation lengths (3 s, 30 s, and 300 s) were used for both pinpoint and one-zero sampling, resulting in six data sets for the two recording techniques.

***Response duration***

This simulation was developed for state behaviours, which may be of some length. Three levels of behavioural duration were selected; these were short (3 second), medium (30 seconds) and long (300 seconds) durations.

The observation period was set to one hour in length (3600 seconds), with the chosen behaviour occurring once per ten-minute period. This meant that the behaviour occurred six times during the hour period, with the long behaviour taking up 50% of the hour, the medium behaviour taking up 5%, and the short behaviour 0.5%. A random number generator was used to determine where each behavioural duration would occur within its ten-minute block.

As for the *Response frequency* test, a continuous data set was developed by using the raw, simulated data and transforming this into percentages. Each of the three behaviour durations (short, medium and long) were measured using one-zero and pinpoint sampling. Three interval lengths, again consisting of 3 seconds, 30 seconds and 300 seconds, were used for both the one-zero and the pinpoint sampling. Once complete, the results were then transformed into percentages and compared to the continuous data.

***Simulations and Statistical Analysis***

**RESULTS**

**From Simon Tuke to Everyone: 01:14 AM**

**https://r4ds.had.co.nz/**

**From Simon Tuke to Everyone: 01:39 AM**

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**DISCUSSION**

**CONCLUSIONS**

**Acknowledgements**

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