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# ANALYSING MOTION PICTURE CUTTING RATES

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**Abstract:** This article refocuses attention onto cutting rates in motion pictures, which have largely been ignored in quantitative studies of film style in favour of shot lengths. I clarify the concept of a rate in statistics and define two equivalent versions of cutting rate in motion pictures. I show that the introduction of the average shot length as a statistical film style was based on a flawed understanding of statistical theory and that it is not a measure of cutting rate, with the result that the tendency of researchers to quote the average shot length as a measure of rate leads to flawed analyses of film style. I demonstrate some simple methods for visualising and analysing cutting rates illustrated by concrete examples for data collected from slasher films.

## 1. Introduction

Research on cutting rates has shown that they effect the viewers' attention and arousal (Bradley, et al., 2003; Cooper, et al., 2009; Kostyrka-Allchorne, et al., 2017; Lang, Bolls, et al., 1999; Ludwig and Bertling, 2017), comprehension (Davies, et al., 1985; Penn, 1971), memory (Kraft, 1986; MacLachlan and Logan, 1993; Lang, Zhou, et al., 2000), and emotional responses (Heft and Blondal, 1987) to motion pictures.

Karen Pearlman (2015: 55) writes that cutting rate 'is not just another way of saying "duration of shots" although the two ideas do overlap,' and distinguishes between the different ways in which motion picture editors shape the rhythm of a film by controlling the *timing* of shots – choosing a frame to cut on, the placement of a shot within a sequence, and the length of time a shot is held on screen – and the *pacing* of a film, by controlling the rate at which cuts occur (Pearlman 2017). However, it is generally the case that when scholars discuss the cutting rate of a film, they do so in terms of shot duration, typically expressed in the form of a single figure – the average shot length (ASL). For example, David Bordwell uses the concepts of ASL and cutting rate interchangeably: 'In the mid- and late-1960s, several American and British filmmakers were experimenting with faster cutting rates. Many studio-released films of the period contain ASLs between six and eight seconds, and some have significantly shorter averages' (2002: 17). Similarly, Yuri Tsivian argues that we can track historical change in editing patterns by 'comparing their prevailing ASLs' of different historical eras to 'get a sense of how cutting rates changed over the last hundred years' (2009: 95). Sam Roggen (2019) directly conflates cutting rate and ASL to define the former in terms of the latter, referring to 'cutting rates (quantified as average shot length).' There are many other examples to be found in the literature of this usage of the ASL.

It is rare for film scholars who base their discussions of film style on statistical methods to report any statistics other than the ASL. Bordwell and Roggen, for example, refer to no other statistics to describe editing in the cinema. This is because most researchers quoting ALSs do not, in fact, collect any shot length data and rely upon dividing the running time by the total number of shots. When they do refer to other statistics the same confusion between shot lengths and cutting rates is also evident. For example, Tsivian (2009: 96) refers to *cutting swing*, which is simply the standard deviation of a film's shot lengths, and *cutting range*, which is the difference between the shortest and longest shots in a film, as statistics descriptive of a film's cutting rate even though they are defined as descriptive statistics of shot lengths. The visualisations of the trends in shot durations presented by Tsivian (2009), and which are widely available on the Cinemetrics database (http://www.cinemetrics.lv), are also based on the description of trends in shot lengths and contain no information about a film's cutting rate.

Despite the claims of researchers to be analysing them, cutting rates have been largely overlooked in quantitative research on film editing which has tended to focus on shot lengths. This may be attributed to the improper use of the ASL as a measure of the cutting rate which has forestalled work in this area. Consequently, a range of statistical methods that could profitably be employed to analyse style in the cinema have been ignored. It is the objective of this article to refocus attention onto cutting rates. I clarify the concept of a rate in statistics and define two equivalent versions of cutting rate in motion pictures. I show that while the cutting rate is mathematically related to the ASL, they are conceptually distinct. I review Barry Salt's 1974 article, 'Statistical Style Analysis of Motion Pictures', to show how this piece sowed the seeds of confusion that are still evident in quantitative approaches to film editing. I go on to describe some simple methods for visualising and analysing cutting rates illustrated by concrete examples for data collected from slasher films and to explain why these methods are preferable to commonly-used approaches, perhaps the best known of which is Cinemetrics.

## 2. The average shot length is not a measure of cutting rate

### *2.1 Some definitions*

A *rate* is a measure of the frequency of some phenomenon of interest per unit of time expressed as the ratio between the total frequency and the total time elapsed (Everitt and Skrondal, 2010: 358):

$$r = \frac{frequency}{time}.$$

In writing on film, there are two definitions of cutting rate, *r*. Karen Pearlman (2019: 153), for example, defines cutting rate in terms of *cuts (c) per unit of time* that is calculated as the total number of cuts divided by the running time of the film:

$$r_c = \frac{number\ of\ cuts}{running\ time}.$$

Cut here really means *transition*, and so includes fades, dissolves, and other types of transitions along with hard cuts, where the moment of transition from shot A to shot B (such as the midpoint of a dissolve) is marked as a cut. Alternatively, Raymond Spottiswoode (1973: 45), for example, defines the cutting rate in terms of the number of *shots (s) per unit of time* that is calculated as the number of shots divided by the running time of the film:

$$r_s = \frac{number\ of\ shots}{running\ time}.$$

A *shot* is defined between the as the amount of time elapsed between two cuts.

We can represent the running time of a film as a line and mark the points in a film at which cuts occur (Figure 1). Indeed, this is how timeline-based editing functions in non-linear editing software and so it is natural to conceive editing in this way. There is a one-to-one correspondence between cuts and shot lengths, and the time at which the *k*-th cut occurs is equal to the sum of the lengths of the prior shots. There is one less cut point than the number of intervals created by dividing a line into segments and so the number of shots in a film will always be $c + 1$: to produce a film comprising 100 shots we need to make 99 cuts. Consequently, $r_c$ will be slightly different to $r_s$, but if we allow the end of the final shot to be classed as a cut to define its duration, then the two definitions are equivalent. For example, in Figure 1 we have a hypothetical film with 100 cuts (including the end of the final shot) and 100 shots, and a running time of ten minutes to give

$$r_c = r_s = \frac{100}{10} = 10 \; cuts(shots) \; per \; minute \, .$$

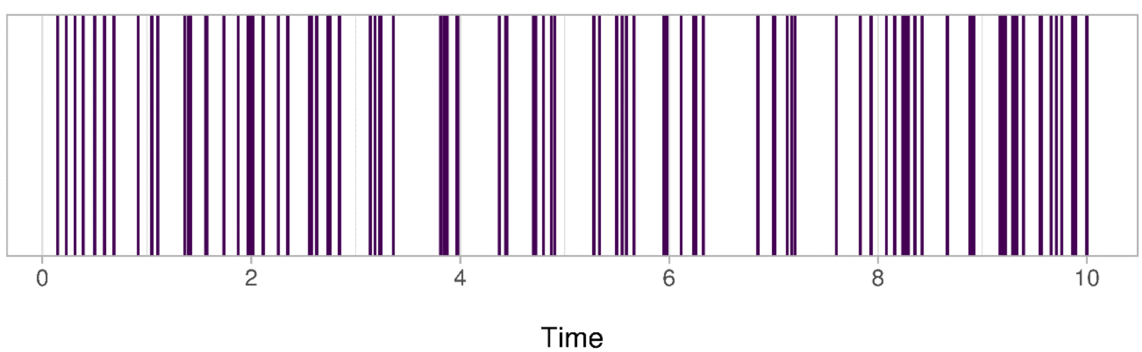


**Fig. 1: A hypothetical film with 100 cuts (including the end of the final shot) and 100 shots with a running time of 10 minutes. Each vertical line marks the point at which a cut occurs.**

It is immediately obvious that the ASL does not describe the cutting rate of our hypothetical film because it is *not* a rate. The ASL is defined as the mean time elapsed between two cuts and is expressed as the ratio of the total running time of a film and the number of cuts (shots):

$$ASL = \frac{running \; time}{number \; of \; cuts \;\; (shots)} \, .$$

For our hypothetical example, this means we must wait 1/10th of a minute, or 6 seconds, on average until a cut occurs. This does not meet the above definition of a rate because it does not express a frequency of events per unit of time. Phrasing the mean waiting time as a rate, i.e., '6 seconds per cut,' could imply the cut has duration which is not our intent and is potentially confusing when some types of transition (such as fades or dissolves) do have duration even though we treat them as cuts for the purposes of analysis. However, it is common to use the ASL as a measure of cutting rate. For example, Barry Salt uses as a measure of cutting rate, which he defines in the glossary to *Moving into Pictures* as 'How many shots there are in a fixed length of film. Measured by Average Shot Length (ASL) (q.v.)' (2006: 409; this quote is rendered as it is in the source), leading us to look up the definition of the ASL which he gives as 'The length or running time of a film, …, divided by the number of shots' (2006: 407). The definition of the cutting rate is clearly at odds with the definition of the ASL, and Salt conflates these two concepts. As the ASL is the reciprocal of the cutting rate multiplied by the unit of time ($1/r \times t$) there is clearly a mathematical relationship between these two concepts, but it is a basic error to treat them as equivalent because they are conceptually different, measuring different things and requiring different methods of analysis.

### *2.2 The origins of the average shot length*

To understand how the ASL became confused with the cutting rate it is necessary to go back to Salt's 1974 article, 'Statistical style analysis of motion pictures', in which he presented the average shot length as a statistic of film style, though, in fact, no definition of the ASL is given in this paper.

Describing his initial results, Salt notes that there is a 'considerable similarity' in the overall shape in the frequency distributions of shot lengths and that the Poisson distribution is an approximate model of those frequency distributions, though no evidence of goodness-of-fit is provided to illustrate this point:

> The profiles of the distributions approximate in nearly all cases to that of the Poisson distribution – the distribution of randomly arrived at events or quantities observed with such things as the distance between cars on a highway.
>
> (Salt, 1974: 15)

Salt later concludes that the approximation to the Poisson distribution explains the lack of temporal structure in films, though he admits this represents only a 'superficial inspection' of the data:

> That there is no overall patterning in the succession of shot lengths in the films is suggested, though of course it is not proven, by the conformity of the shot length distributions to the Poisson type of random distribution.
>
> (Salt, 1974: 20)

Salt ties the Poisson distribution to the ASL noting that there are some deviations from this model 'appropriate to the different average shot lengths' (1974: 15) – an early indication that he was conflating two concepts in his statistical analyses. Ultimately, he concludes that between the films in his sample, with few exceptions, 'there is no real differentiation … other than would be equally well provided by the average shot length alone' (1974: 15). This statement is the basis for over 40 years of researchers reporting the ASL – and, in most cases, *only* the ASL – as a statistic of film style.

Little came of the suggestion that shot lengths can be adequately modelled by the Poisson distribution, and Salt (and others) moved on to considering various other distributional models for shot lengths; but understanding the role of the Poisson distribution in the logic of Salt's article is key to understanding why the ASL is used to describe cutting rates.

### *2.3 The Poisson and exponential distributions*

The Poisson distribution is a discrete distribution used to model the count data of the number of events occurring in a given time interval of a stochastic process and has only one parameter: the mean number of events in a time interval, $\lambda$, which is called the *rate*. The probability mass function of a random variable $X$ with a Poisson distribution ($X \sim Pois(\lambda)$) is

$$p(X = x) = \frac{\lambda^x e^{-\lambda}}{x!}, x \geq 0, \lambda > 0 .$$

The number of events expected in any time interval of length $t$ is $\lambda t$. If counting the number of events in any fixed size interval will produce data that is Poisson distributed, then that stochastic process is a *Poisson process*. If a random variable $X$ is Poisson distributed with rate parameter $\lambda$, then the time elapsed between occurrences of $X$ has an *exponential distribution* with the same rate parameter $\lambda$ and mean $1/\lambda$. The exponential distribution is the probability distribution of the time between events of a Poisson process, and 1/λ multiplied by the size of the time interval *t* is the mean waiting time. The probability density function of a random variable *Y* with an exponential distribution (*Y* ~ *exp*(λ) is

$$p(Y = y) = \lambda e^{-\lambda y}\, , for\ y \geq 0, \lambda > 0\ .$$

It is clear that the smaller the value of λ, the longer the expected waiting time between events; and that larger values of λ will result in shorter expected waiting times.

Figure 2 shows the relationship between the Poisson and exponential distributions for different values of λ. Though they are related, the Poisson and exponential distributions describe distinct types of variables. This is why the Poisson distribution has a *mass* function and the exponential distribution has a *density* function. The Poisson distribution is a *discrete* distribution: in Figure 2.A the mass functions of the Poisson distributions can only be calculated when the variable *X* is a whole number (*X* = 0, 1, 2, 3, …) that represent the number of events in a unit of time. The exponential distribution is a *continuous* distribution: in Figure 2.B the variable *X* can take on any value in a continuous range (*Y* = 0.2, 1.4, 2.0, 3.9, …), and so the densities of the exponential distributions can be calculated for any value on the *x*-axis.

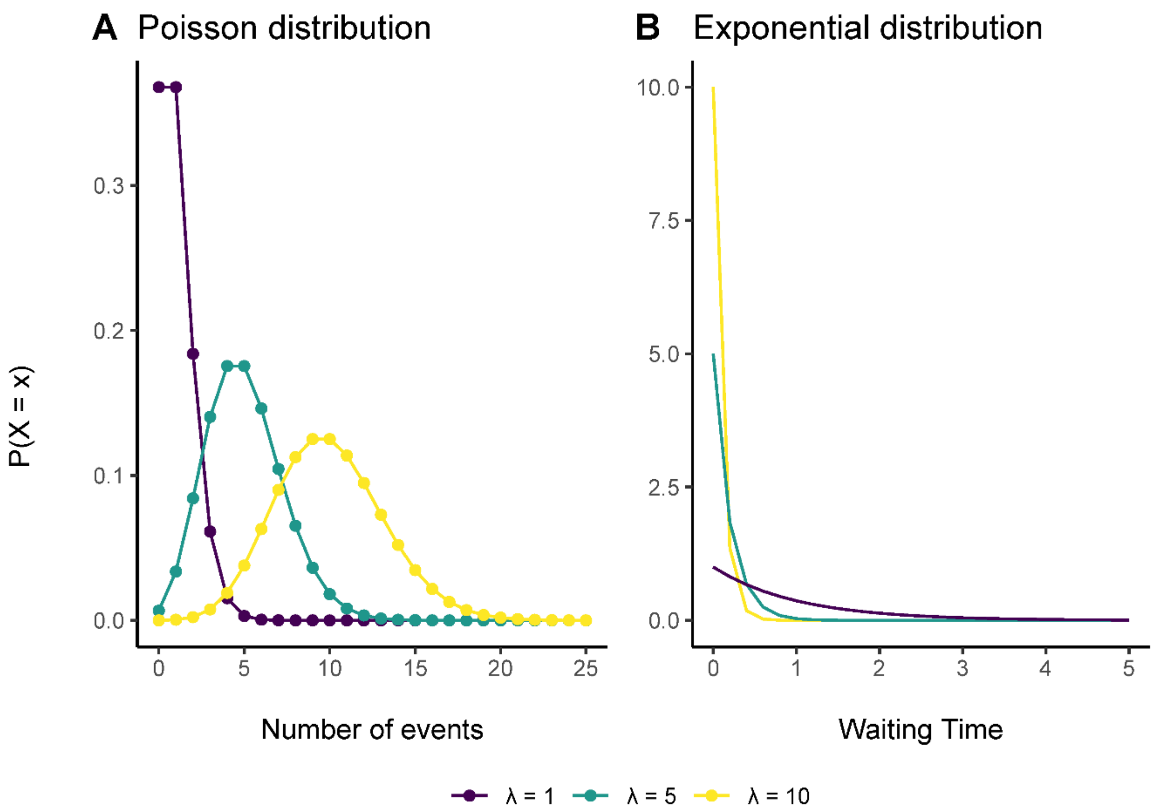


**Fig. 2: (A) Poisson distributions with λ = 1, 5, 10. (B) Exponential distributions for λ = 1, 5, 10.**

The relationship between the parameters of the Poisson and exponential distributions is the same relationship between the cutting rate and the ASL: the mean time between events ($1/\lambda \times t$) is the reciprocal of the rate at which events occur multiplied by the size of the interval. In our hypothetical example in Figure 1, assuming the validity of the approximation to a Poisson distribution, we have a rate (λ) of ten cuts per 60-second interval and so the mean waiting time for a cut is $1/10 \times 60 = 6$ seconds. If $t = 1$ second, then the cutting rate is simply 1/ASL, when the ASL is expressed in seconds. Both the Poisson and the exponential distributions require only a single parameter to specify their complete probability distributions. This is why Salt argues that, because the distribution of shot lengths is apparently approximated by 'the Poisson type of random distribution' and that distribution has a single parameter, we can describe the cutting rate of a film with a single number: the ASL.

This logic is flawed because the distribution of shot lengths in a film cannot be approximated by a Poisson distribution. Reconstructing Salt's methodology, we see that his first step was to bin the shot lengths to produce a frequency distribution showing the number of shots that fall within a range of duration and presented as a table on page 16 of his 1974 article. This frequency distribution was then compared to a Poisson distribution. It was, however, incorrect to do so. Salt is evidently confused about applications of the Poisson distribution when he states that it is used to model 'such things as the distance between cars on a highway,' because while we might use the Poisson distribution to model the number of cars that arrive at a fixed point on a highway in an interval of time, the distance between cars on the highway is a continuous variable and cannot be modelled in this way (Gerlough, 1955: 25). The confusion here lies in the fact that Salt has binned a continuous variable (shot length) and then treated it as a discrete count variable (the number of shots per unit of time) when these are conceptually distinct entities. This explains why Salt describes the cutting rate of a film using the ASL even though it is not a measure of a rate. This error has been replicated throughout film studies with the result that numerous studies of editing that purport to analyse cutting rates in fact *contain no information about cutting rates whatsoever*.

Figure 3 presents the data for *Slumber Party Massacre* (1982) and will allow us to clarify the problem here and to understand some basic statistics. Both plots in Figure 3 involve binning the data but are conceptually quite different.

Figure 3.A presents the observed number of cuts per 30-second interval in the film. To produce this plot, I *divided the running time of the film* into non-overlapping bins of 30 seconds in length and counted the number of cuts occurring in each bin. I then plotted the results in a *bar chart*, where the height of each column represents the number of 30-second intervals containing a given number of cuts. For example, there are sixteen 30-second intervals containing 5 cuts. Notice that the binning process for this procedure applies to the running time of the film and *not* to the duration of the shots in the film, which have not been considered at any stage of this process. Also notice that the variable on the $x$-axis is *discrete*: the number of cuts in any 30-second interval must be a whole number. Figure 3.A contains no information about the duration of shots in this film.

Figure 3.B presents the distribution of shot lengths in *Slumber Party Massacre*. To produce this plot, I binned the data *by dividing the range of the shot lengths* into non-overlapping bins of 1 second and counted the number shots with duration between the upper and lower limits of those bins. Unlike the bar chart in Figure 3.A, I use a *histogram* to visualise the results because the $x$-axis now represents a *continuous* variable that can take on any value on the line (though in practice I rounded the shot length data to one decimal place). Each column in this histogram represents the

number of shots with duration between the upper and lower limits of each bin, and frequency is expressed by the *area* of the column and not by its height. For example, there are 154 shots in this film with duration between 0.95 and 1.95 seconds. Figure 3.B contains no information about the temporal structure of the film.

For completeness, we see that *Slumber Party Massacre* has an ASL of 5.7 seconds, and so the rate parameter, λ, for the fitted Poisson distribution is equal to 1/5.7 × 30 = 5.26. Figure 3.A shows this is clearly not an adequate model for the observed data. It is trivial to point out the distribution of shot lengths in Figure 3.B cannot be adequately modelled by an exponential distribution.

The Poisson distribution is not an appropriate statistical model for motion picture shot lengths, but could it be used to model the cutting rate of a film? The simple answer is no. It is clear from Figure 3.A that the Poisson distribution is a poor empirical fit for a particular film, but there are general theoretical reasons for rejecting this model for all films. Poisson processes have a number of assumptions:

1. two events cannot occur at exactly the same instant;
2. events are *independent* – the occurrence of one event does not affect the probability a second event will occur; and,
3. the expected number of events per unit of time (λ) is constant and has a Poisson distribution ($X \sim Pois(\lambda)$) – the probability distribution of the number of events occurring in any time interval depends only on the length of the interval because λ is identical for all intervals.

This model is unrealistic for motion picture cutting rates because Poisson processes are useful for applications involving temporal uniformity (Streit, 2010: 1). In fact, only the first of these assumptions is valid for the editing in a motion picture: two cuts cannot occur at the same time and each shot must have a duration of at least one frame. For a motion picture, the probability of a cut occurring at any time is not independent of previous cuts, and the time series will often exhibit a trend to faster of slower cutting over the course of a film while also demonstrating acceleration and deceleration of the cutting rate because different types of sequences in a film are characterised by different editing regimes. Consequently, we expect to see clusters of long and short takes in a motion picture and so the assumption of a Poisson process will not be appropriate. For example, DeLong (2015: 45-46) demonstrates that Hollywood films released between 1935 and 2005 exhibit a tendency for shots to cluster together and are constructed in a non-random way. The presence of any trends will mean that the process does not satisfy stationarity; that is, the statistical properties of the time series will not be identical at different points in the process. For example, James Cutting (2016) shows that shot duration in Hollywood cinema evolves over the course of a film and is related to narrative structure.

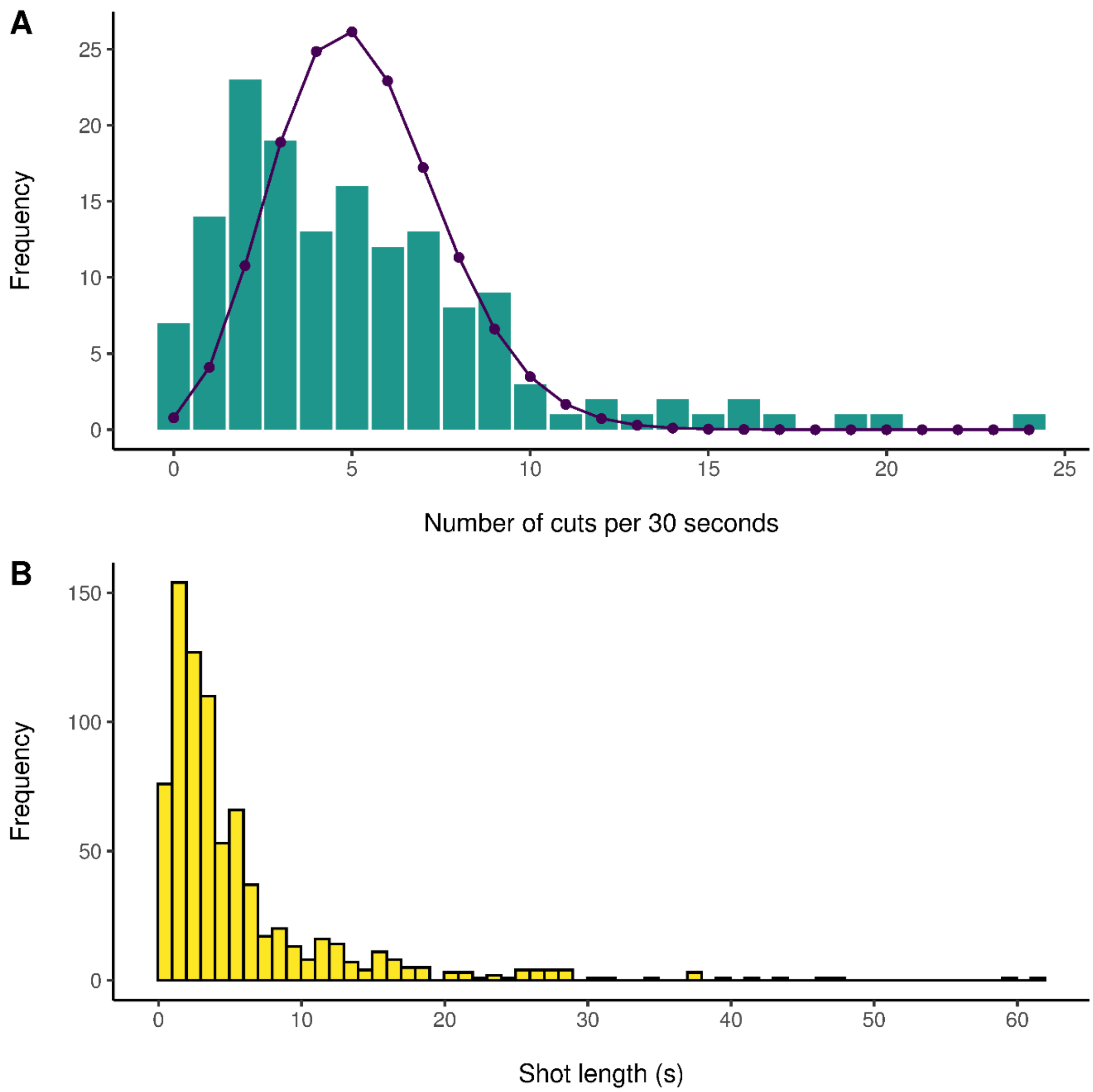


**Fig. 3. (A) The observed number of cuts per 30-second interval in *Slumber Party Massacre* (1982), with fitted Poisson distribution (λ = 5.26). (B) Histogram of shot lengths in *Slumber Party Massacre* with a bin width of 1 second.**

## 3. Analysing cutting rates

The introduction of the ASL as a statistic of film style was conceptually flawed and the ASL does not describe the cutting rate of a film. Some authors use the ASL as a statistic of film style to describe and compare motion picture shot length distributions without referring to cutting rates, a use of the ASL that is also problematic (see Redfern, in press), but the relationship between the cutting rate and ASL has persisted in the literature on quantitative analyses of film editing for almost half a century. Again, although these are related concepts, the ASL and the cutting rate are not interchangeable. Analysing cutting rates requires a mental adjustment in the way in which we think statistically about film editing, leaving behind the concept of shots to focus on cuts. It is the cutting rate we are interested in, after all. In this section I introduce some core concepts needed to analyse cutting rates and describe some simple methods to this end using shot length data for some slasher films.

### *3.1 Film editing as a point process*

Analysis of motion picture cutting rates requires us to think of the editing of a film as a *simple point process* (Jacobsen, 2006). A simple point process is a stochastic process whose realizations comprise a set of point events in time, which for a motion picture is simply the set of times ($T$) at which the cuts occur: $T = \{t_k, \ldots, t_K\}$, where $t_k$ is time of the $k$-th cut in seconds since the beginning of the film and $K$ is the total number of cuts in the film. In practice, $t_k$ will mark the end of the last shot of a film. As above, a shot, $s$, is defined as the time elapsed between two cuts: $s_k = t_k - t_{k\text{-}1}$. Every point process is associated with a *counting process*, defined as the number of events ($N$) that have occurred up to and including time $t$: $N(t)$. A counting process has integer values that are (1) non-negative ($N(t) \geq 0$), (2) non-decreasing ($N(t_2) > N(t_1)$ if $t_2 > t_1$), and (3) the number of events in any interval $[t_1, t_2)$ is equal to the difference between the counts at two different times ($N(t_2) - N(t_1) = N[t_1, t_2)$).

Perhaps the simplest way to visualise the evolution of the cutting rate of a film is to plot $N(t)$ against $T$ to produce a *step function plot*. If the cutting rate is constant, then the cumulative number of cuts will increase linearly at a 45-degree angle with slope = 1. Slower cutting rates will still increase the cumulative count but at a shallower angle (slope < 1) as the running time of the movie is used up without consuming a large number of cuts, while faster cutting rates will be evident when the plot rises non-linearly due to there being many cuts in a brief period of time (slope > 1). One advantage to plotting the step function rather than the shot lengths of a motion picture is that the latter can be noisy making it harder to identify how the editing changes.

Figure 4.A plots the step function for *Friday the Thirteenth* (1980) and allows us to identify various interesting structural features. The opening sequence of the film set in the 1950s comprises the first 17 shots of the film and is edited slowly. The cutting rate picks up once the film shifts to the modern day (shots 18-144) and establishes the locations and characters. This section can be divided into three sub-sections following Annie's journey to the campsite (18-74) and her brutal demise (123-144) and the arrival of the new counsellors at the campsite (75-122), showing that the film uses different cutting rates for different sequences in different locations with different characters. The cutting rate slows for the main part of the film as life at the campsite (145-262) segues into the stalk-and-slash section (263-399) of the film. Within this section the cutting rate jumps for the murders of Marcie (273-280) and Brenda (318-323) before returning to its sedate cutting rate. The cutting rate increases sharply for the final girl sequence (400-534) in which Alice tries to survive the repeated attacks of Mrs. Vorhees, with slower moments of cutting separating the different assaults in this part of the film. The cutting rate of the film slows for the coda (535-559) when Alice wakes up in the hospital and is similar to the cutting rate at the beginning of the second section of the film. From this plot we are therefore able to identify the overall structure of the film, picking out features in the evolution of the editing at different scales.

This method can be extended to compare multiple films with different running times and different numbers of cuts by normalising both $T$ and $N(t)$ to unit vectors. To normalise the cut times, we simply divide the time of each cut by the total running time of a film. Similarly, to normalise the counting process to a unit vector we divide the cumulative count of cuts by the total number of cuts to express $N(t)$ as a proportion over the range [0, 1].

Comparing the normalised step function of *Friday the Thirteenth* to that of its reboot in Figure 4.B it is evident that there is far less variation in the cutting rate in the 2009 version. The step function of the 2009 film does not show the same large changes in slope over the course of its running time. Also, the same non-monotonic trend seen in the step function of the original film is not evident here. Instead, the cutting rate shows the film is divided into two main sections, with those sections separated by sequences where the cumulative count increases rapidly. The film opens with a brief prologue (normalised count: 0.00-0.03), before the first of two stalk-and-slash sequences. The first of these sequences follows a group of friends on a camping trip at Crystal Lake thirty years after Jason Vorhees watched his mother be decapitated by a camp counsellor, and he proceeds to murder them one by one until taking the last, Whitney, captive. This sequence (0.03-0.21) has a constant cutting rate until the end of this sequence, when the rate increases sharply. From this point the cutting rate of the increases, slowly at first (from 0.21 to 0.65) and then more rapidly as the film heads towards its conclusion. This shift almost two-thirds of the way through the film is associated with the end of Clay's exploration of the campsite as he searches for the missing Whitney (his sister) and Jason's invasion of the cabin where he will murder assorted holidaymakers. There is, however, no sudden increase in the cutting rate in the final fifth of the film corresponding to the original version because there is no 'final girl' sequence similar to that of the 1980 movie. In fact, there is no final girl in this film: the role of investigator who learns the truth about the terrible place is assigned to Clay and, while Whitney is seemingly able to defeat Jason after pretending to be Mrs. Voorhees, she is – ultimately – just another victim. As in the 1980 version, the cutting rate jumps when Jason murders his victims, as can be seen, for example, at 0.62 and 0.69, but these are less easily distinguished from the background rate.

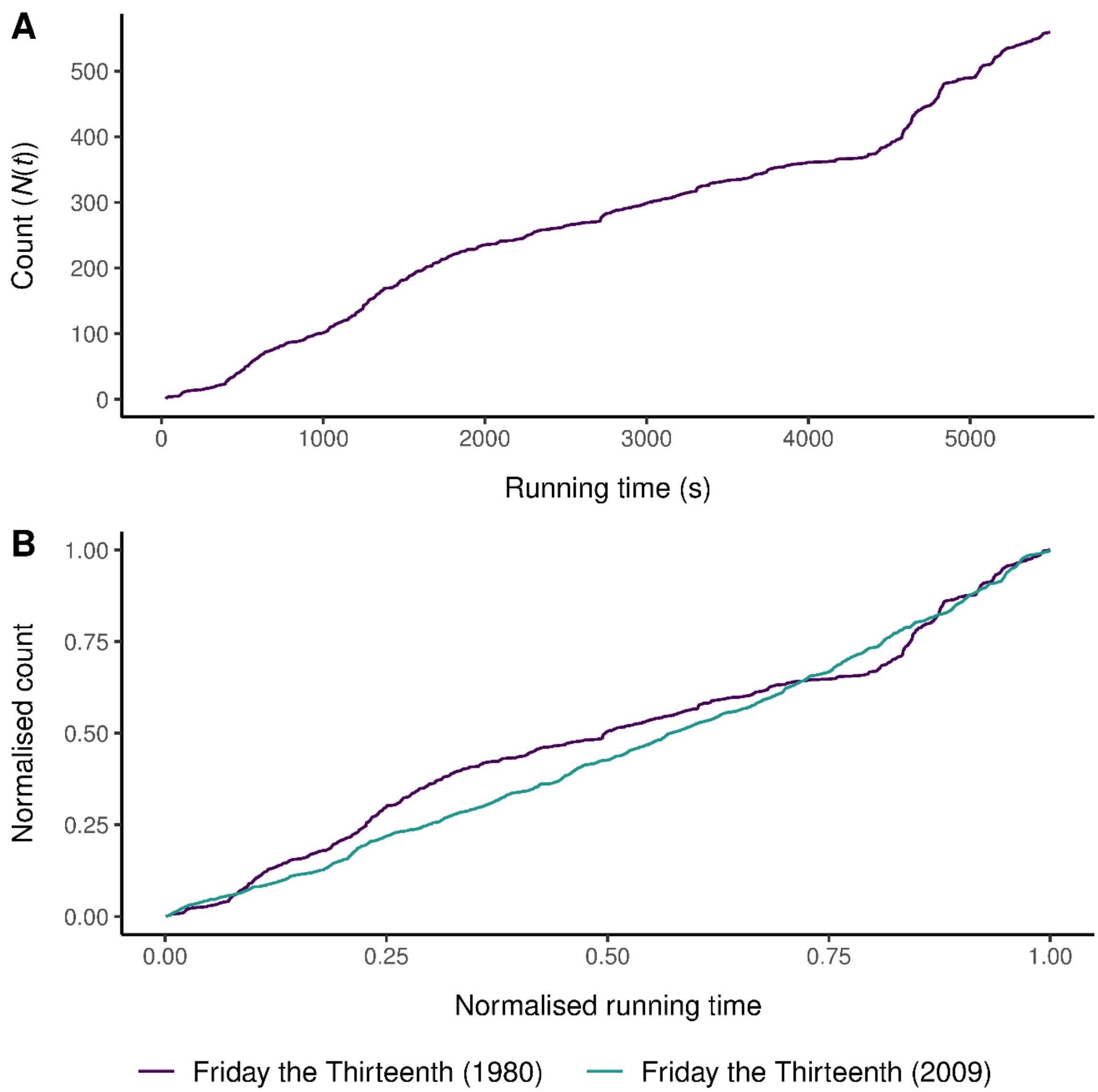


**Fig. 4. Visualizing the editing of slasher films as a point process. (A) The step function of *Friday the Thirteenth* (1980). (B) The normalised step functions of *Friday the Thirteenth* and its 2009 reboot, *Friday the Thirteenth*.**

### *3.2 Instantaneous and cumulative cutting rates*

Having defined the cutting rate in terms of a simple point process characterised by $N(t)$ and $T$ we can derive some useful statistics to describe the editing of a film. The *instantaneous cutting rate* ($r_i$) is the time derivative of $N(t)$, differencing the $k$-th counts and cut times $n$ steps apart:

$$r_i(t) = \frac{dN(t)}{dt} = \frac{N(t_k) - N(t_{k-n})}{t_k - t_{k-n}}.$$

This is equal to the slope of the cumulative plot of the counting process between cuts $n$ steps apart. If $n = 1$, and letting $N(0) = 0$ and $t_0 = 0$ seconds, then $r_i(t) = 1/(t_k - t_{k-1})$ and is equal to the reciprocal of the shot lengths. The *cumulative cutting rate* ($r_\Sigma$) is the ratio of the number of cuts that have occurred by time $t$ divided by the time elapsed:

$$r_\Sigma = \frac{N(t)}{t}.$$

At the end of the film $N(t)$ will be the total number of cuts in the film and $t$ will be the running time of the film, and so $r_\Sigma = 1/\text{ASL}$. The plot of $r_\Sigma$ will always evolve to this point.

Figure 5.A plots the instantaneous cutting rate ($n = 1$), and Figure 5.B plots the cumulative cutting rate for *Slumber Party Massacre*. These plots show similar information in different formats, with the cumulative cutting rate plot less noisy than the instantaneous rate, though the cumulative rate is less flexible as different values of $n$ could be chosen to calculate the instantaneous rate. The cutting rate of *Slumber Party Massacre* is slowest at the beginning of the film before dropping at 460.5 seconds when the girls shower after a basketball game and the camera lingers on their bodies – this is a 1980s' slasher movie, after all. From the end of this sequence at 649.1s to 1467.7s, the cutting rate is constant before slowing down once the action shifts to the beginning of the slumber party. After 2680.3s the cutting rate increases with the first intrusion of violence into the when the pizza delivery boy arrives dead, before slowing down in anticipation of the film's violent finale. The virtuoso piece of editing in *Slumber Party Massacre* is the cross-cutting between the murder of one of the boys at the party and Valerie watching a slasher movie on television. This sequence begins at 3068.2s, comprising 42 cuts and lasting 112.1 seconds, and is edited much more quickly than the scenes that precede and follow it. The return to a slower editing pattern is the sequence running from 3183.9s to shot 3754.0s, focusing on the heroine, Valerie, and her worries that something strange is happening next door, the girls at the party trying to make themselves safe, and the killer, Thorn, hiding the bodies of those who have so far been unfortunate enough to meet him. From the end of this sequence, we move into the final girl sequence which like all first wave slasher movies comprises an increasing cutting rate broken up by slower sections, with the final confrontation coming at 4304.2s and for which the cutting rate is quickest. As above, we are able to identify the overall structure of the film picking out

various aspects of the cutting rate at different scales in order to understand how different editing regimes function at different time in the film.

The last point of the curve in Figure 5.B is the cumulative cutting rate where $r_{\Sigma}$ = 1/ASL. The cumulative cutting rate is below this value for the entire running time of the film, demonstrating that simply taking the reciprocal of the ASL as an estimate of the film's cutting rate in cuts per second will not provide a meaningful description of the film's style. It is clear from the instantaneous and cumulative cutting rates that the cutting rate of *Slumber Party Massacre* is non-stationary, exhibiting a trend to more rapid editing over the course of the film that cannot be summarised in the single statistic – the ASL – most researchers report.

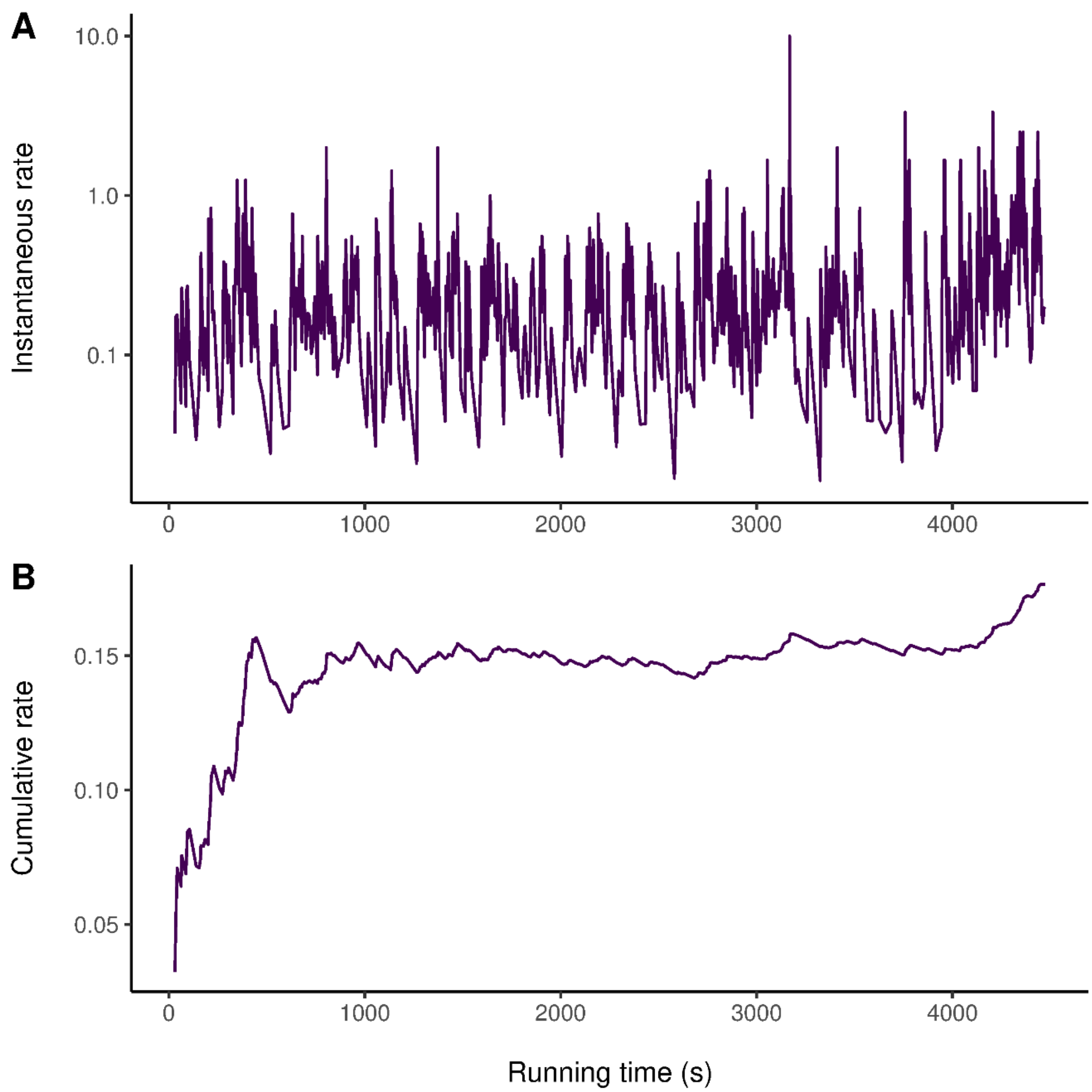


**Fig. 5. The editing in *Slumber Party Massacre* (1982). (A) The instantaneous cutting rate (*n* = 1). (B) The cumulative cutting rate.**

### *3.3 Analysing trend by cut density*

*Cut density* is an uncomplicated way of assessing the cutting rate of a film by fitting a kernel density estimate to the point process. This is often referred to as shot density, but as the mathematical and graphical operations are based on the times of the cuts and not the duration of the shots we should properly refer to cut density. Additionally, shot density is easily confused with the distribution of shot lengths in a film, which is the representation of the variation of shot lengths in a film and is also typically described using some form of density function.

The kernel density is a non-parametric density estimate calculated by summing the kernel functions superimposed on the data at every value on the *x*-axis (Silverman, 1986). The kernel density estimate at a point on the *x*-axis is

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right),$$

Where $n$ is the sample size, $K$ is a kernel function, and $h$ is a smoothing parameter called the *bandwidth* that determines the width of the kernel. This means that we fit a symmetrical function (the kernel) over each individual data point and then add together the values of the kernels so that the contribution of some data point $x_i$ to the density at $x$ depends on how far it lies from $x$. The closer the data points are to one another, the more the individual kernels overlap and the greater the sum of the kernels – and, therefore, the greater the density – at that point. In the context of the cutting rate of a film, the density is greatest when one cut quickly follows another and, therefore, the faster the cutting rate will be at that point in the film; while low densities indicate cuts that are distant from one another on the *x*-axis.

Figure 6.A plots the cut density against the running time of *Halloween* (1978). There are three main parts to the editing structure of the film. The first part of the function is flat as the opening sequence of the film in which the young Michael Myers kills his sister is presented in four shots of 8.3, 8.3, 258.9, and 31.5 seconds, respectively. The main section of the film runs from 307 to 4359.8 seconds and comprises two narrative units. The first part sets out the relationships between the main characters while also tracking Michael on his return to his hometown, before moving into the stalk-and-slash section of the film. Although this section of the movie comprises different locations, time periods, and actions there is no large change in the cutting rate. This is possibly due to the fact that both sequences are organised around creating a pervasive sense of dread punctuated by transitory moments of violence. These moments are evident in Figure 6.A where the density increases sharply before returning to its background level. An example of this can be seen in Michael's assault on the nurse as he escapes the asylum at 505.2-528.6 seconds. The final girl section runs from 4359.8 to 5298.5 as Laurie becomes the sole focus of the narrative with a clear shift to a more rapid editing style at 4650.1 when Michael bursts from the wardrobe and stabs at Laurie. This sequence exhibits two notable features: an increasing trend over the

course of the sequence indicating an intensification in the cutting rate as the intensity of the violence increases; and a series of localised peaks interspersed with lower densities sections when Laurie attempts to raise the neighbours and when she thinks she has killed Michael, allowing the narrative to repeatedly induce a startle response in the viewer as Michael attacks again and again. The closing section of the movie sees the density of cuts fall away as the pace of the movie slows down after the supposed final destruction of Michael.

This method can be easily extended to comparing multiple films. As above, we normalize $T$ by dividing the cut times by the running time of the film to convert $T$ to a unit vector. We also standardize the cut density $f(y)$ of each film to the interval [0, 1] by subtracting the smallest value of $y$ from the $i$-th value of $y$ and dividing by the range,

$$\hat{f}(y) = \frac{y_i - y_{min}}{y_{max} - y_{min}},$$

so that the point at which the density is highest for each film has a value of 1, the point at which density is lowest has a value of 0, and the rest of the values are scaled within this interval. We could compare the non-normalised densities, but it is important to remember that different films will exhibit different variances in their shot lengths, and this may lead incorrect interpretations of the data because what counts as high or low density will be relative to each film.

Figure 6.B plots the normalised densities of *Halloween* and its 2007 remake, *Halloween*. From this plot we see that the remake has a three-part structure based around three main narrative sections: Michael's home life and his time at school, ending with his first killing spree (0.00-0.23); Michael's time at the Loomis institute (0.23-0.54); and, finally, the stalk-and-slash sequence in which Michael returns to Haddonfield for his second murderous rampage (0.54-1.00). Changes in time (Michael as a young boy and as a grown man) and location (Michael at home, at the institute, and in Haddonfield) are marked by low density sections comprising Michael's therapy sessions with Dr Loomis first as a boy (0.23-0.30) and later as a man (0.33-0.38), and Michael stalking the girls after his escape from the institute as Halloween day becomes the deadly Halloween night (0.54-0.60). From Figure 6.B we see that although the second half of these films comprise similar types of sequences – the stalk-and-slash sequence in which the killer dispatches the youth of Haddonfield one-by-one followed by the final girl's confrontation with the killer – they approach

the editing of those sequences differently. In the original version the cutting rate of the stalk-and-slash section (0.45-0.81) is flat and functions as the ground against which the moments of violence stand out; the cutting rate of then increases over the course of the final girl sequence (0.81-0.98) to reach a peak amidst the final confrontation between Laurie and Michael. In the remake this relationship is reversed with an increasing cutting rate across the stalk-and-slash section (0.60-0.80) building to the constant background rate against which the peaks of the final girl sequence (0.80-1.00) stand out.

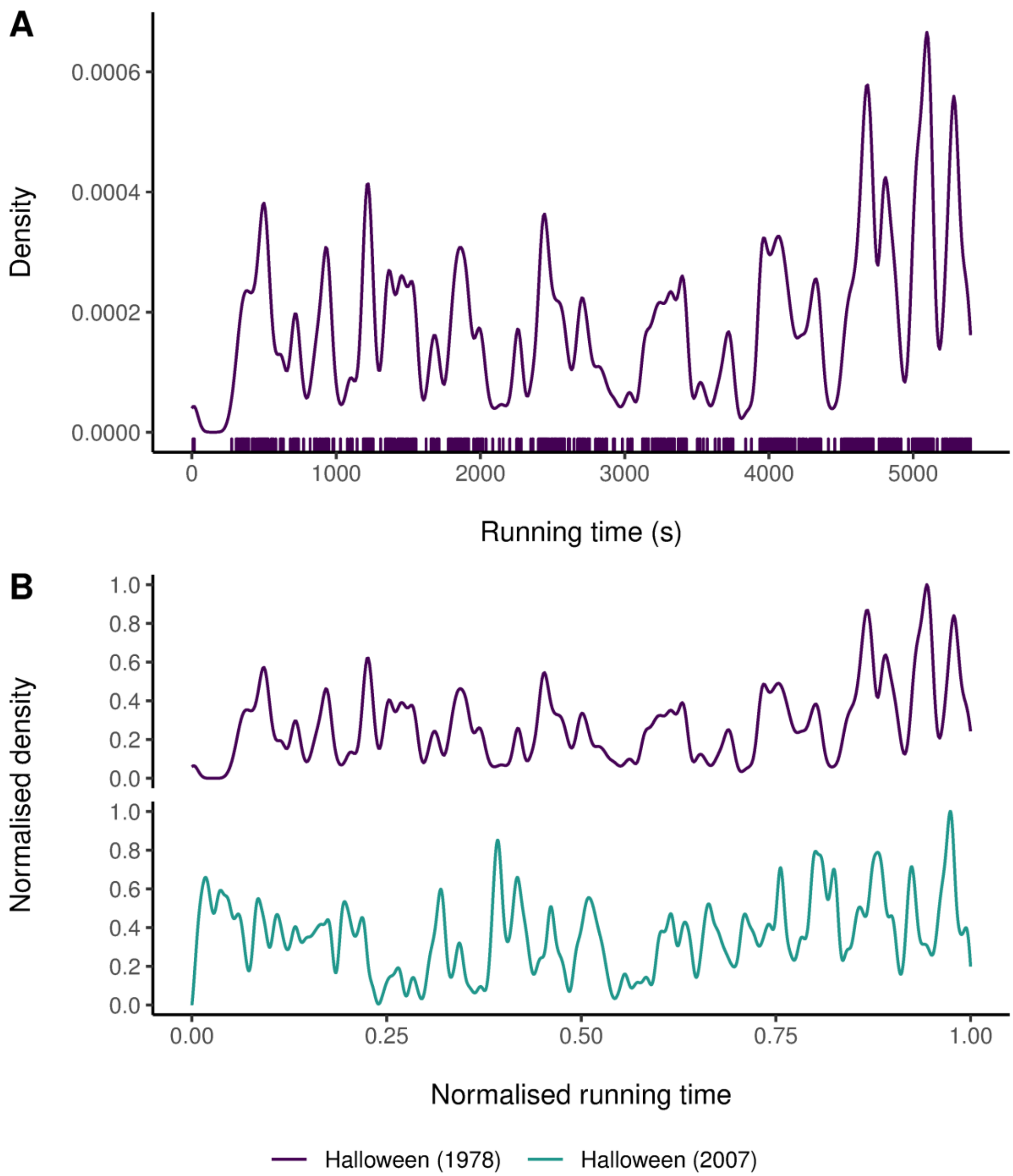


**Fig. 6. Editing patterns in slasher films (A) Kernel estimate of cut density in *Halloween* (1978). (B) The normalised densities of *Halloween* and *Halloween* (2007).**

An advantage of thinking about editing as a point process using the methods described here is that they are simple to interpret because they describe the cutting rate directly. Comparatively, shot durations may be *shorter* or *longer*, but often what we want to describe about a film's editing is *quicker* or *slower* and it is intuitive to depict an *increasing* cutting rate as a rising curve when plotting the step function or instantaneous rate rather than plotting a *decrease* in shot duration. A method employed by researchers using the Cinemetrics database is to plot a polynomial trendline against shot length data. This method is not ideal for a couple of reasons. Polynomial trendlines lack the ability to identify changepoints in a film's style because even with a high-degree polynomial, the trendline is insensitive to changes in style with key features smoothed out, while the coefficients of the polynomial have no meaning in the context of a film's style. Figure 7 plots shot length data for *Halloween* (1978) from the Cinemetrics database (Sittel, 2016) with 6th-degree polynomial trendline and a moving average of 10 seconds. The polynomial does a poor job describing trends in the shot lengths in this film and the polynomial equation of the trendline,

$$y = 6.76 \times 10^{-13}x^6 - 1.13 \times 10^{-9}x^5 + 7.49 \times 10^{-7}x^4 - 2.55 \times 10^{-4}x^3 + 0.05x^2 - 4.20x + 224.20\,,$$

is simply vacuous. The moving average does a better job describing the temporal evolution of the duration of shots but is sensitive to shots with exceptionally long duration. For example, we see that the value of the moving average between 25:44.6 and 30:11.7 in Figure 7 is never below 4.5 seconds and peaks at ~13.6 seconds due to the sensitivity of the mean to shots with a duration much longer than 13.6s, while most shots in this time window are less than 4.5s in duration. This effect can be reduced by shortening the window of the moving average but comes at the cost of increased noise in the trendline that may obscure the features in which we are interested. Neither the polynomial trendline or the moving average contains any information about the film's cutting rate.

Plotting the step function, the instantaneous rate, or the cumulative rate it is immediately obvious when the cutting rate changes, making it easier to identify when changes in a film's style occur. Like the moving average, the cut density in Figure 6 smooths the data with some loss of information, but it is much more sensitive to changes in style than the polynomial trendline without being overly sensitive to shots with exceptionally long duration like the moving average and has the advantage of representing the cutting rate if that is what we intend to plot.

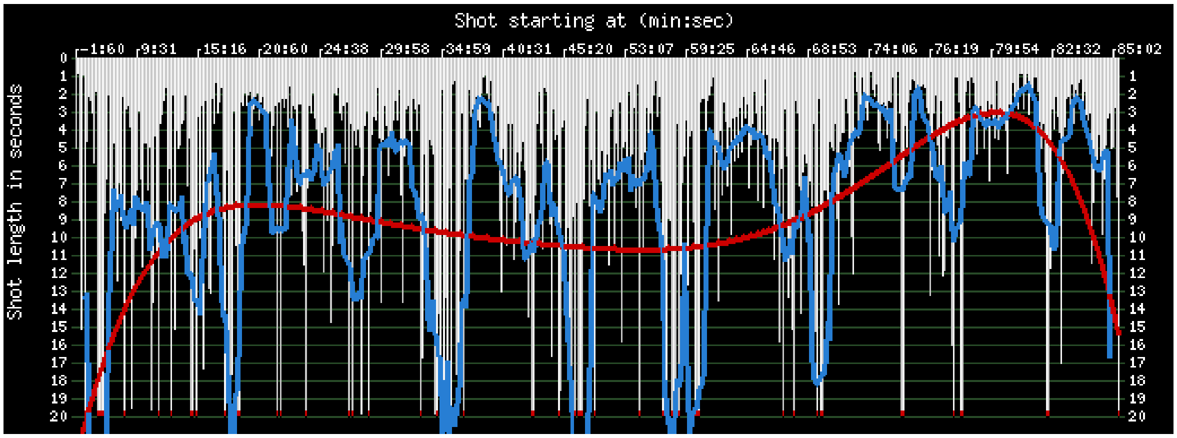


**Fig. 7: Shot length data for *Halloween* (1978) from the Cinemetrics database (Sittel 2016), with fitted 6th-degree polynomial (red line) and a moving average with a 10 second window (blue line).**

## 4. Conclusion

Salt (1992: 146) describes the average shot length as a 'rather obvious concept,' but it is clearly a poorly understood statistic of film style. In this paper I have shown the introduction of the ASL as a statistic of film style is based on a flawed understanding of statistical theory, and that the ASL is improperly used as a measure of cutting rate because it is *not* a measure of a rate and contains no information about the temporal structure of a film.

Despite the range of methods available for analysing film editing (see, for example, Baxter, 2014 or Redfern, 2014), it remains the case that the majority of statistical analyses of film editing follow Salt's original recommendation that a single statistic is sufficient to describe a film's cutting rate and continue to rely solely upon the ASL. For examples of this use of the ASL see not only Bordwell and Roggen, cited earlier, but also Coulthard and Steenberg (2022), Dokic et al. (2020), Olliver (2015), Pérez-Rufí and Valverde-Maestre (2020), and Salt (2020), all of which have been published since 2015. When scholars do go beyond the ASL, this misinterpretation is also evident in other statistics such as the so-called 'cutting swing' or 'cutting range' that also contain no information about cutting rates and which have no simple interpretation in the context of a film's pacing: what is 'swinging' when we refer to 'cutting swing'? How does it relate to the rate at which cuts occur? And why does the standard deviation measure it?

To understand motion picture cutting rates it is necessary to make a conceptual shift in the quantitative analysis of film style away from focusing on shot duration and to approach editing as a point process. To that end, I have demonstrated some simple methods for analysing cutting rates that enable the researcher to identify interesting features in the editing of motion pictures at different scales and to compare the editing of different films. The methods demonstrated here have a key advantage over those currently used for statistical analysis of film style, such as the statistical summaries and visualisations available on the Cinemetrics website, all of which are based on shot lengths and contain no information about cutting rates. To express it in Pearlman's (2017) terminology, they represent timing but not pacing and, while there is clearly a mathematical relationship between shot duration and cutting rate, they tell us nothing about cutting rates. The methods described above are simple to implement and represent the pacing of a film. If film scholars wish to employ quantitative summaries as a starting point for discussions of style in the cinema, it is a basic requirement that the descriptive statistics and visualisations presented as part of any analysis of film editing should have a clear meaning and contain information about the phenomenon they purport to describe. Current practices in the statistical analysis of film style suggest that this is not presently the case.

Once progress is made in understanding the defining features of cutting rates in it will be possible to move on to the next stage and to develop models of motion picture editing capable of describing and simulating their temporal structure. A key question to address is what type of point process is motion picture editing? We know that editing is not a random process, being non-stationary and exhibiting clustering, and so we can already begin to identify some possible models for consideration. As I demonstrated in section 2, film editing is not a Poisson process, but could it be adequately modelled as a self-exciting point process with a conditional rate function such as a Hawkes process (Hawkes 2018)? Given that we know that cutting rates evolve according to the narrative structure of a film and tend to shift between sections edited cut more slowly and those that are edited quickly, could we mark each cut to indicate the state of the film at the time at which that cut occurs and employ Markov-modulated Hawkes processes (Wang et al., 2012) as a potential model? These are questions of practical import when it comes to understanding how films work and to applications of artificial intelligence to filmmaking and the development of data-driven artificial intelligence-based editing systems (Leake et al., 2017). Simulating the editing patterns of films will depend on being able to construct models of the film editing as a point process and those simulations will be based on analyses of cutting rates in the cinema.

**Data Availability**

The shot length data for the slasher films is available under a Creative Commons Attribution 4.0

International license and can be accessed at: Redfern, Nick. (2020). Slasher film editing data [Data set]. Zenodo. https://doi.org/10.5281/zenodo.3787825.

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