A graphical method to aid the sequential analysis of observational data

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In this paper, two methods of sequential analysis are applied to hypothetical observational data. The first method employs the conventional "conditional probability" approach, illustrated using the GSEQ program (Bakeman & Quera, 1995). In order to overcome some of the difficulties associated with the conditional probability approach, the second method employs a new "normalized and pooled" approach. Essentially, by normalizing periods of time preceding, during, and following each occurrence of a nominated "given" behavior, the proportion of time units devoted to a "target" behavior can be estimated and then pooled across all occurrences of the given behavior. A summary diagram representing the likelihood that the target behavior precedes, occurs concurrently with, and follows the given behavior can then be constructed. Elements of this summary diagram can also be quantified. Given the graphical nature of the output, and its ease of use, the normalized and pooled approach may help to promote the use of sequential analysis in applied settings.

The analysis of complex social interactions has attracted increasing interest in the last 15 years. Prominent targets for study have included the mother-child relationship (Adamson & Bakeman, 1985; Bakeman & Brown, 1977; Dowdney, Mrazek, Quinton, & Rutter, 1984; Gottman & Ringland, 1981), husband-wife interactions (Gottman, 1979; Gottman, Markman, & Notarius, 1977), the client-counselor process (Hill, Carter, & O'Farrell, 1983; Lichtenberg & Heck, 1986; Patterson & Forgatch, 1985), and, more recently, the relationship between problem behaviors and environmental events (Lerman & Iwata, 1993; Mace & Lalli, 1991). In an attempt to quantify various aspects of interactions, many studies have employed observational methodology. This involves systematically observing and recording the behaviors of two or more individuals, usually in naturalistic settings. Given computerized methods of data capture, this has now become a less onerous task than it once was (see Noldus, 1991; Repp & Felce, 1990; Repp, Harman, Felce, Van Acker, & Karsh, 1989; Tapp, Wehby, & Ellis, 1995; Unwin & Martin, 1987). For instance, behaviors can now be recorded in either "event" or "interval" units, be defined as "momentary" and/or "duration" (see Sackett, 1979), and saved in either a "continuous" or an "intermittent" format. The data can then be subjected to analysis.

Although each recorded behavior can be expressed as a rate or percentage of the total observation period, these

"time-budget" measures do not provide information concerning the *process* of the interaction (Bakeman & Gottman, 1986)—that is, the relationship between behaviors. Many studies have therefore attempted to detect naturally occurring chains of behaviors in the observational data (see Patterson, 1974). However, a simple, yet effective and useful methodology for analyzing sequential data has proved elusive (Gottman & Roy, 1990). Previous descriptions of methods of sequential analysis (e.g., Budescu, 1984; Gardner & Griffin, 1989; Gottman, 1981; Iacobucci & Wasserman, 1988; Moran, Dumas, & Symons, 1992) and software for conducting sequential analysis (e.g., Noldus, 1991; Repp & Felce, 1990; Sackett, Holm, Crowley, & Henkins, 1979) require considerable time and statistical expertise in terms of conducting the analysis itself and interpreting the subsequent output (Bakeman & Casey, 1995; Hall, 1995; Highlen, 1986; Lichtenberg & Heck, 1986; Sackett, 1987). Sequential analysis has therefore not been utilized by practicing behavior analysts in clinical settings.

Some of the difficulties with sequential analysis have now been resolved. For instance, Bakeman and Quera (1992) have developed a standard format for representing observational data collected using different methods (i.e., the *sequential data interchange standard*, or *SDIS*). A software package for data analysis has also recently appeared (i.e., the *Generalized Sequential Querier*, or *GSEQ*, Bakeman & Quera, 1995). However, some difficulties with the application and interpretation of sequential analysis methods remain. In order to illustrate these difficulties, a hypothetical example will be considered, and a new graphical method of sequential analysis will then be described. The new method is designed primarily to help promote the use of sequential analysis by practicing behavior analysts in clinical settings and not as a replacement for existing methods of sequential analysis.

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Example Data

Suppose two behaviors, X and Y, were observed in a naturalistic setting. Behavior X, for instance, could represent the “gaze” of a young child, whereas behavior Y could represent the “vocalization” of his/her mother. Hypothetical data for the dyad are displayed at the bottom of this page.¹ These data follow SDIS conventions (Bakeman & Quera, 1995). The first line in the data (i.e., Timed X Y;) indicates that two behavior codes were recorded in continuous mode. The second line (i.e., ,1) indicates that the observation session started at the first time unit. The following lines contain the main observational data. Each recorded behavior occurrence has three components: a letter indicating which behavior was emitted, its onset time, and its subsequent offset time. The right parenthesis following each offset time unit indicates an inclusive offset time unit (see Bakeman & Quera, 1995). Inspection of the data above shows that behaviors X and Y can co-occur (e.g., at time units 100 and 101). The last line in the data (i.e., ,547)/) indicates that the observation session finished at time unit 547. This particular data format has been called *timed sequential data (TSD)* and is considered to capture “real-life complexity” (Bakeman & Quera, 1995, p. 14).

The “Conditional Probability” Approach

Conventional methods of sequential analysis adopt the “transitional” or “conditional probability” approach (Bakeman, 1978). The conditional probability of a “target” behavior reflects the likelihood of its occurrence given that another “given” behavior has occurred. Thus, in the example data shown above, the probability of Y given X, or $p(Y/X)$, and the probability of X given Y, or $p(X/Y)$, are statistical descriptions of the association between X and Y. Quantification of the association can most easily be achieved by comparing each conditional probability with its respective unconditional probability (i.e., the proportion of time allocated to the behavior). Thus, a higher (or lower) value obtained for the probability of Y given X, when compared with the unconditional probability of Y, indicates a likely association between X and Y. Similarly, a higher (or lower) value obtained for the probability of X given Y, when compared with the unconditional probability of X, also indicates a likely association between X and Y. The magnitude of the effect can be gauged using an appropriate statistic—for example, Yule’s Q or the log-odds ratio (Wickens, 1993).

The temporal association between X and Y (i.e., whether the target behavior precedes, occurs during, or

follows the given behavior) can be indicated by adding a subscript to the notation given above. Thus, to evaluate the temporal association between X and Y, the probability that Y precedes X could be represented by the notation $p(Y_{-1}/X)$, the probability that Y occurs during X could be represented by the notation $p(Y_{+0}/X)$, and the probability that Y follows X could be represented by the notation $p(Y_{+1}/X)$. Similarly, the probability that X precedes Y could be represented by the notation $p(X_{-1}/Y)$, the probability that X occurs during Y could be represented by the notation $p(X_{+0}/Y)$, and the probability that X follows Y could be represented by the notation $p(X_{+1}/Y)$. Thus, six conditional probabilities can be evaluated to reflect the association between X and Y.

To illustrate the conventional conditional probability approach to sequential analysis, an analysis will be conducted on the hypothetical data given above using the GSEQ program. GSEQ is a command-based program that requires the user to create an ASCII input file of commands. For instance, in order for the program to calculate the conditional probability of Y occurring during X—that is, $p(Y_{+0}/X)$ —the following commands would be required in the GSEQ input file:

```
File “xy”;
Stats CONP;
Target Y &;
Given X &;
End;
```

The first line (i.e., File “xy”;) indicates that the data file is called xy.sds. The second line (i.e., Stats CONP;) requests conditional probability values. The third and fourth lines (i.e., Target Y &; and Given X &;) request conditional probability values for the target behaviors, Y and not-Y (the latter represented by &), given the given behaviors X and not-X. The last line (i.e., End;) finishes the program run. The conditional probability values actually calculated by GSEQ are simply the number of time units during which the target and given behaviors co-occur divided by the number of time units during which the respective given behaviors occur (cf. “nested” analysis; Noldus, 1991; Repp & Felce, 1990). For instance, if X occurs for 120 time units and X and Y co-occur for 35 time units, then the conditional probability of Y occurring during X is .29 (i.e., 35 divided by 120). However, the calculation of conditional probabilities for Y preceding X, or for Y following X, is more difficult. Here, GSEQ allows the user to specify time “windows” (i.e., periods of time keyed to the onset or offset of behaviors). Time windows are essen-

```
Timed X Y;
,1
X,15-22) Y,23-39) X,83-88) X,92-101) Y,100-116) X,144-150) Y,150-165) X,181-186) Y,183-204)
X,250-256) Y,255-268) X,302-311) X,316-345) Y,320-336) X,365-372) Y,368-386) X,404-411)
Y,408-425) X,457-470) Y,482-487) X,508-513) Y,514-532)
,547)/
```

tially additional variables that are created at run time and can therefore be used in the subsequent analysis. For example, issuing the commands:

```
Window PREX = (X-10,(X-1;  
Window FOLX = X)+1,X)+10;
```

after the first line in the GSEQ input file given above generates two new variables, PREX and FOLX. The first variable, PREX, would occur 10 time units before the onset of each occurrence of X to 1 time unit before the onset of each occurrence of X. The second variable, FOLX, would occur 1 time unit after the offset of each occurrence of X to 10 time units after the offset of each occurrence of X. Exchanging X in the GSEQ input file given above for PREX or FOLX would then allow the program to calculate the conditional probability of Y preceding X or the conditional probability of Y following X. One disadvantage of the window command, however, concerns the problem of "overlapping" time windows. For instance, by specifying a time window of 10 sec, a period of 10 sec after the offset of a given behavior may overlap with a period 10 sec before the onset of the next given behavior, or even with the next occurrence of the given behavior. As Bakeman and Quera (1995) explain:

The windows ... are affected by the timing of the codes already in the file, and occasionally this very flexibility can result in anomalies. Some windows may extend before the beginning or after the end of the session, in which case they are truncated. Others may overlap, in which case the later windows are truncated. Still others may be null (i.e., have no duration). (p. 76)

Employing a 10-sec time window on the example data given above would produce an overlapped time window (i.e., the window following "X,83-88") would overlap with the window preceding "X,92-101"). Although this would have a minimal effect on the interpretation of the results in this example, anomalies may become substantial on larger data sets, particularly when behaviors cluster together (i.e., they have short bout and interbout durations). Thus, it appears that an analysis employing a time window would be entirely satisfactory only if the periods of time between occurrences of a behavior were always more than twice the desired time window. Since this is unlikely (unless the time window specified is extremely short), the analysis process requires the investigator to make a "decision" concerning the length of the time window in order to minimize the anomalies. Clearly, different specifications will produce quite different results.

Still, there is a solution to the overlap problem within this approach. For example, when the time between the offset of a given behavior and the onset of its next occurrence is less than twice the desired window (e.g., 10 sec), then whatever time is available can be split—the first half assigned to time after the first behavior, and the sec-

ond half assigned to time before the next occurrence.² Therefore, once GSEQ has issued a warning that a window variable has created overlaps, the window variable could be coded manually so that the time between any overlaps is split. For instance, in the example data, given that GSEQ flagged an overlap for the window variable PREX, the variables PREX and FOLX were coded manually (using the splitting procedure for the one overlap) and placed in the data file before running GSEQ. Due to the work involved, however, this procedure would seldom be done without the aid of a computer program. Still, the window command in GSEQ can be used to define the variables PREY and FOLY (i.e., 10-sec time periods preceding and following Y) since these variables do not overlap (at least with the 10-sec window used here). The input GSEQ command file and corresponding data file necessary to conduct this "modified" analysis are shown in the Appendix. Figure 1 shows selected parts of output given by GSEQ.

Each 2×2 table in Figure 1 contains conditional probability data for a target behavior given a given behavior or created window variable. For instance, the table at the top left of Figure 1 shows that the conditional probability of Y preceding X, or $p(Y_{-1}/X)$, is .00 (i.e., the value in the top left cell of the table). Yule's Q for the table is -1.00 . It can therefore be stated that Y is less likely to occur preceding X. Looking at the middle left table in Figure 1, we can see that the conditional probability of Y during X, or $p(Y_{+0}/X)$, is .29 (Yule's $Q = -.03$). Thus, Y is neither less likely nor more likely to occur during X. The conditional probability of Y following X, or $p(Y_{+1}/X)$, can be found in the bottom left table in Figure 1. Here, the conditional probability is .77 (Yule's $Q = .87$). Thus, Y is more likely to occur following X. Interpreting these results in terms of the example behavior codes (i.e., X representing child gaze and Y representing mother vocalize), it appears that mother vocalize occurs at a lower level prior to child gaze and at a higher level following child gaze.

The top right table in Figure 1 shows that the conditional probability of X preceding Y, or $p(X_{-1}/Y)$, is .48 (Yule's $Q = .66$). Thus, X is more likely to occur preceding Y. The middle right table in Figure 1 shows that the conditional probability of X during Y, or $p(X_{+0}/Y)$, is .21 (Yule's $Q = -.03$). Thus, X is neither less likely nor more likely to occur during Y. The bottom right table in Figure 1 shows that the conditional probability of X following Y, or $p(X_{+1}/Y)$, is .09 (Yule's $Q = -.54$). Thus, X is less likely to occur following Y. Again, interpreting these results in terms of the example behavior codes, it appears that child gaze occurs at a higher level prior to mother vocalize and at a lower level following mother vocalize. In summary then, the six tables presented in Figure 1 tell the same story (i.e., they are six views of the same data)—specifically, that mother vocalize often followed child gaze.

Given		Target	
		Y	&
PREX		0.0000	1.0000
&		0.3725	0.6275
		Yule's Q = -1.0000	

Given		Target	
		X	&
PREY		0.4800	0.5200
&		0.1611	0.8389
		Yule's Q = 0.6556	

Given		Target	
		Y	&
X		0.2917	0.7083
&		0.3044	0.6956
		Yule's Q = -0.0305	

Given		Target	
		X	&
Y		0.2121	0.7879
&		0.2225	0.7775
		Yule's Q = -0.0305	

Given		Target	
		Y	&
FOLX		0.7692	0.2308
&		0.1919	0.8081
		Yule's Q = 0.8670	

Given		Target	
		X	&
FOLY		0.0900	0.9100
&		0.2483	0.7517
		Yule's Q = -0.5392	

Figure 1. Selected output obtained from the GSEQ program following issue of the commands and modified example data listed in the Appendix. Cells in the tables contain conditional probabilities. The Yule's Q statistic is shown below each table.

The "Normalized and Pooled" Approach

In order to overcome some of the difficulties encountered when conducting the conditional probability approach and to provide a useful graphical aid to sequential analysis, a "normalized and pooled" approach is proposed.³ The method proceeds as follows. Each i th occurrence of a given behavior (e.g., X) is examined in turn, beginning at the 2nd occurrence of the given behavior and ending at its penultimate occurrence.⁴ Three "periods," consisting of time units, are then imposed on the data:⁵ (1) *preceding* (from the midpoint between the time unit following the offset of the i th - 1 occurrence and the time unit before the onset of the i th occurrence, denoted a_1 , to the time unit before the onset of the i th occurrence, denoted b_1); (2) *during* (from the onset of the i th occurrence, denoted a_2 , to its offset inclusive, denoted b_2); and (3) *following* (from the time unit following the offset of the i th occurrence, denoted a_3 to the midpoint between a_3 and the time unit before the onset of the i th + 1 occurrence, denoted b_3). The third column of Figure 2 shows the time units for the three periods: preceding, during, and following each i th occurrence of X in the example data.

Next, for each i th occurrence of the given behavior, the time units at which a target behavior (e.g., Y) co-occurs in each period is noted. If a target behavior co-occurs in a preceding period, its onset time unit is denoted c_1 and its offset time unit is denoted d_1 . If a target behavior co-occurs in a during period, its onset time unit is denoted c_2 and its offset time unit is denoted d_2 . Finally, if a tar-

get behavior co-occurs in a following period, its onset time unit is denoted c_3 and its offset time unit is denoted d_3 . The fourth column of Figure 2 shows the time units at which the target behavior Y co-occurs in each of the three periods for each i th occurrence of the given behavior X in the example data.

Because each period consists of differing time unit lengths, each period is normalized in order to produce time periods of equal length, and the proportion of time units at which the target behavior co-occurs in each of the three periods of each i th occurrence of the given behavior is calculated. This is done using the following equation:

$$\text{percentiles} = \frac{c_x - a_x}{(b_x - a_x) + 1} \times 100 \text{ to } \frac{(d_x - a_x) + 1}{(b_x - a_x) + 1} \times 100,$$

where $x = 1, 2, \text{ or } 3$ (i.e., preceding, during, or following periods, respectively). The fifth column of Figure 2 shows the resulting percentile data for each period and each occurrence of the given behavior X in the example data.

To illustrate, for the 3rd occurrence of X in the example data, the time units for the following period are 102 to 122, (therefore, $a_1 = 102$, and $b_1 = 122$; see Figure 2, column 3). The time units at which Y co-occurs in the period are 102 to 116, (therefore, $c_1 = 102$, and $d_1 = 116$; see Figure 2, column 4). Using the equation above,

<i>i</i> th occurrence of X	Period	Time units for each period	Co-occurrence of Y in each period	Percentiles for each period
2	Preceding	53-82)		
	During	83-88)		
	Following	89-90)		
3	Preceding	90-91)		
	During	92-101)	100-101)	80 to 100
	Following	102-122)	102-116)	0 to 71
4	Preceding	123-143)		
	During	144-150)	150	86 to 100
	Following	151-165)	151-165)	0 to 100
5	Preceding	166-180)		
	During	181-186)	183-186)	33 to 100
	Following	187-218)	187-204)	0 to 56
6	Preceding	218-249)		
	During	250-256)	255-256)	71 to 100
	Following	257-279)	257-268)	0 to 52
7	Preceding	279-301)		
	During	302-311)		
	Following	312-313)		
8	Preceding	314-315)		
	During	316-345)	320-336)	13 to 70
	Following	346-355)		
9	Preceding	355-364)		
	During	365-372)	368-372)	38 to 100
	Following	373-388)	373-386)	0 to 88
10	Preceding	388-403)		
	During	404-411)	408-411)	50 to 100
	Following	412-434)	412-425)	0 to 61
11	Preceding	434-456)		
	During	457-470)		
	Following	471-489)	482-487)	58 to 90

Figure 2. Time units for the three "periods" preceding, during, and following each *i*th occurrence of X, time units for the co-occurrence of Y in each period, and percentiles of time units for the co-occurrence of Y in each period in the example data.

$$\begin{aligned} \text{percentiles} &= \frac{102 - 102}{(122 - 102) + 1} \\ &\times 100 \text{ to } \frac{(116 - 102) + 1}{(122 - 102) + 1} \times 100 = 0 \text{ to } 71. \end{aligned}$$

The percentiles at which Y co-occurs in the following period are therefore 0 to 71 (i.e., Y co-occurs in the first 72 percentiles of the period; see Figure 2, column 5).

In order to calculate the mean probability of a target behavior occurring at a given percentile for each period of the given behavior, the total number of occurrences of the target behavior occurring at each percentile is pooled across all occurrences of the given behavior for each period. To illustrate, in the example data, behavior Y co-occurs at percentile 0 in the following period of the 3rd, 4th, 5th, 6th, 9th, and 10th occurrences of X. The total number of pooled occurrences of Y occurring at per-

centile 0 of the following period is therefore 6. The total number of occurrences of the target behavior occurring at each percentile is then divided by the total number of occurrences of the given behavior considered (i.e., if X is nominated the given behavior in the example data, the total number of occurrences of the target behavior Y occurring at each percentile would be divided by 10). Considering the example again, the probability of Y occurring at percentile 0 in the following period would thus be .6.

A summary diagram of the probability of the target behavior preceding, occurring during, and following the given behavior can now be constructed. The resulting diagrams for the example data with X as the given behavior and Y as the target behavior (upper panel) and with Y as the given behavior and X as the target behavior (lower panel) are shown in Figure 3.

Figure 3. Plot of the mean probability of Y at each percentile preceding, during, and following X (upper panel), and plot of the mean probability of X at each percentile preceding, during, and following Y (lower panel).

The profile in the upper panel of Figure 3 shows that the probability of Y remains at 0 preceding X, increases from 0 to .6 during X, and decreases from .6 to about .1 following X. The profile in the lower panel of Figure 3 shows that the trend is almost the inverse of the upper panel in Figure 3. Here, the probability of X increases from 0 to about .9 preceding Y, decreases from about .9 to about .1 during Y, and continues to decrease to 0 following Y.

In order to quantify the profile in some way, a "profile score" for each period can be derived as follows. For each period of the profiles shown in Figure 3, the proportion of profile under the curve represents the probability of the target behavior occurring over that period. Similarly, the proportion of profile above the curve represents the probability of the target behavior not occurring over that period. For instance, for the preceding period of the profile in the upper panel of Figure 3, the proportion of profile under the "curve" is 0, whereas the proportion of profile above the curve is 1.00. Two cells of the familiar 2×2 table for the period are now known (i.e., the probability of Y preceding X and the probability of not-Y preceding X). To complete the table, the probability of Y and not-Y not preceding X must be calculated. This is done by coding for the absence of the period preceding X and then conducting the normalized and pooled approach, nominating not-preceding-X as the given behavior and Y as the target behavior. The proportion of profile under the curve over the during period of this profile thus represents the probability of Y not preceding X. Similarly, the proportion of profile above the curve over the during period represents the probability of not-Y not preceding X. The table is now complete. A profile score for the period can now be calculated from the probability data in the 2×2 table, for instance, by use of the formula for Yule's Q (see Bakeman & Quera, 1995). Profile probability data and profile scores for each period of the profiles in Figure 3 are shown in Figure 4.

Interpreting the results in terms of the example behavior codes, mother vocalize appeared to be presented during child gaze and subsequently removed following child gaze. Conversely, child gaze appeared to be presented prior to mother vocalize and removed during and following mother vocalize (cf. conditional probability analysis above).

It should be stressed at this point, however, that the profile scores do not in any way determine the strength of a causal relationship. This is also true of Yule's Q in the conditional probability analysis. It is quite possible, for instance, that X and Y in the example data are the results of another behavior, Z, with Y simply having a larger latency time than X. This possibility will be illustrated as follows.

Suppose the observer had recorded five more behaviors (e.g., Z, A, B, C, and D), in addition to X and Y. (The codes could represent additional behaviors of the child and/or its mother or even behaviors of additional participants.) The complete data file is shown at the top of the next page.

In order to determine whether Z may be associated with X and/or Y, behavior Z could be nominated the given be-

Timed X Y Z A B C D;

,1
Z,1-21) D,7-17) X,15-22) Y,23-39) Z,40-49) D,50-58) B,59-69) Z,65-84) X,83-88) A,85-99) X,92-101)
Y,100-116) B,116-126) Z,126-144) X,144-150) Y,150-165) Z,166-182) X,181-186) Y,183-204) Z,204-220)
D,221-225) Z,225-252) X,250-256) Y,255-268) Z,269-286) C,282-291) Z,292-302) X,302-311) A,309-319)
X,316-345) Y,320-336) D,337-343) Z,344-367) X,365-372) Y,368-386) B,387-392) Z,393-406) X,404-411)
Y,408-425) Z,426-438) D,439-445) Z,445-457) X,457-470) A,458-468) Z,469-481) Y,482-487) Z,487-507)
X,508-513) Y,514-532) Z,533-547)
,547)/

havior with behaviors X, Y, A, B, C, and D nominated the target behaviors. The results of the analysis, using the normalized and pooled approach, are shown graphically in Figure 5.

The top left profile in Figure 5 shows that the probability of X is low prior to Z, increases during Z, and is high immediately following Z, decreasing thereafter. This indicates an association between Z and X similar to the association between X and Y (cf. Figure 3, upper panel). This profile can be contrasted to the profile obtained between behavior Z and behavior Y (top right of Figure 5). Here, the probability of Y decreases prior to Z, is at a low level during Z, and increases following Z. This indicates that Y is most likely to occur at the midpoint between occurrences of Z. Profile scores for behaviors X and Y preceding, occurring during, and following Z are shown in Table 1, together with profile scores for behaviors A, B, C, and D preceding, occurring during, and following Z.

Although the analysis is still incomplete (we have not, for instance, examined the profile with X as the given behavior and Z as the target behavior), the data serve to illustrate that the method is also useful in more complex

situations. Indeed, the method has indicated that behavior B may also be associated with Z (see middle right profile of Figure 5, and Table 1). Of course, these results do not preclude the possibility that behaviors X and Y could be associated with yet another event that has not been monitored. The important point to note here, however, is that associations between behaviors can be graphically displayed and quantified in a meaningful way.

Discussion

We have devised a new method for conducting sequential analysis both in an attempt to overcome some of the difficulties associated with conducting a conditional probability approach to sequential analysis and to provide an accessible method of sequential analysis for clinicians. Essentially, by normalizing periods of time prior to, during, and following each occurrence of a nominated given behavior, the proportion of time units devoted to a target behavior can be estimated and then pooled across all occurrences of the given behavior. A summary diagram can then be constructed that represents the likelihood that the target behavior precedes, occurs concurrently

Given		Target	
		Y	&
Preceding X		0.0000	1.0000
	&	0.4465	0.5535
		Profile score = -1.0000	
Given		Target	
		Y	&
During X		0.3030	0.6970
	&	0.2430	0.7570
		Profile score = 0.1505	
Given		Target	
		Y	&
Following X		0.4614	0.5386
	&	0.1505	0.8495
		Profile score = 0.6573	

Given		Target	
		X	&
Preceding Y		0.3614	0.6386
	&	0.1708	0.8292
		Profile score = 0.4863	
Given		Target	
		X	&
During Y		0.2537	0.7463
	&	0.2288	0.7712
		Profile score = 0.0680	
Given		Target	
		X	&
Following Y		0.0705	0.9295
	&	0.3342	0.6658
		Profile score = -0.7375	

Figure 4. Profile data for each period of the profiles shown in Figure 3. Cells in the tables contain probability data over each period. Profile scores are shown below each table.

Figure 5. Plots of the mean probability of X, Y, A, B, C, and D at each percentile preceding, during, and following Z.

with, and follows the given behavior. The normalized and pooled approach to sequential analysis therefore offers a relatively straightforward method of detecting and quantifying the temporal association between two behaviors.

We believe that the new method has a number of benefits for clinicians. First, the normalized and pooled method does not require the investigator to determine the duration of time windows, each of which may affect the

Table 1
Profile Probability Data and Profile Scores
for Each Period of the Profiles Shown in Figure 5

Behavior Code	Period					
	Preceding Z		During Z		Following Z	
	Probability	Score	Probability	Score	Probability	Score
X	.14	-.24	.09	-.59	.38	.66
Y	.56	.76	.01	-.97	.45	.50
A	.07	-.02	.00	-1.00	.16	.80
B	.12	.83	.02	-.53	.00	-1.00
C	.07	.49	.02	-.60	.07	.49
D	.19	.56	.01	-.93	.21	.73

subsequent outcome and interpretation of the results. Second, because the method normalizes periods of time prior to, during, and following occurrences of behaviors, the problem of "overlapping," "truncated," and "null" windows is avoided and, hence, anomalies occurring in the analysis are also avoided (see Bakeman & Quera, 1995). Although this problem can be corrected somewhat by splitting the time between occurrences of a given behavior when it is less than twice the desired window (see Appendix), this still requires careful manipulation of the data file. Third, the analysis summarizes the relationship between the two behaviors in one profile that, we believe, is intuitively appealing and easy to understand and interpret. Finally, elements of the profiles obtained from the method can be quantified to a profile score, which can then be subjected to further analyses.

This method of analysis also has a number of implications for studying social interactions. For instance, interpreting the results of the normalized and pooled approach in terms of the example behavior codes; it could be argued that the child's behavior served to occasion the behavior of its mother (see during and following periods of Figure 3, upper panel). Conversely, it could be argued that the mother's behavior served to remove the child's behavior (see during and following periods of Figure 3, lower panel). If this interpretation is correct, it is likely that each participant in the interaction is influenced by the other's behavior (i.e., the child's behavior is influenced by the repeated presentation of the mother's behavior contingent on the child's behavior; similarly, the mother's behavior is influenced by the repeated removal of the child's behavior contingent on the mother's behavior). This relationship is indicative of the notions of "control and countercontrol" (Skinner, 1953) and "coercion" (Patterson, 1982; see also Oliver, 1995).

An additional benefit concerns the detection of intermittent responses to behaviors. Because the method described here determines the relative trend of one behavior occurring prior to, during, and following another behavior, sequences of behaviors that may occur reliably but also intermittently may also be detected. Thus, it is the profile that is produced from the data that may suggest a relationship between behaviors and not necessarily the significance of a conditional probability over its unconditional probability.

One disadvantage of the normalized and pooled method is that the approach appears to be applicable only to timed sequential data (TSD) (Bakeman & Quera, 1995). Thus, data collected in other formats are not amenable to this method of analysis. Further refinement of the methodology described here, perhaps for use with other data formats, would therefore be warranted. Further problems with the method may also need to be investigated. For instance, the consequences of analyzing data files with small numbers of given behaviors is unclear. We believe that data files containing less than 10 occurrences of a given behavior would supply an insufficient number for analysis. (The example data contained small numbers of given behaviors for illustration purposes only.)

Furthermore, it is unclear whether longer time periods between successive occurrences of events are necessarily functionally equivalent to shorter ones, as the method implies (i.e., periods of 2 time units are treated as equivalent to periods of 100 time units). Indeed, the method also treats each "durational" time unit as functionally equivalent. This is also true of the conditional probability approach described here. It could be argued, for instance, that the onset of a behavior is more important than its duration. To investigate this possibility, the method could be adapted so that 2 time periods are defined rather than 3 (i.e., *preceding*, from the midpoint between the time unit following the offset of the i th - 1 occurrence and the time unit before the onset of the i th occurrence, denoted a_1 , to the time unit before the onset of the i th occurrence, denoted b_1 ; and *following*, from the onset of the i th occurrence, denoted a_2 , to the midpoint between a_2 and the time unit before the onset of the i th + 1 occurrence, denoted b_2).

A final point concerns under what circumstances an investigator might choose to use the conditional probability approach or the normalized and pooled approach. Clearly, if an investigator wanted to determine whether or not a target behavior was more (or less) likely to occur within x seconds of a given behavior, then the conditionally probability approach should be chosen. However, if an investigator wanted to determine whether or not a target behavior was either presented or removed relative to the occurrence of a given behavior, then the normalized and pooled approach should be chosen. Choosing the latter approach would also allow occurrences of

a target behavior further removed in time from a given behavior to be included in the analysis.

In summary then, the methodology described here may provide a useful additional method with which to study social interactions. Indeed, the method may be particularly valuable to those without the statistical expertise or time to do a thorough conditional probability analysis. To this end, a computer program to conduct the normalized and pooled approach to sequential analysis is available from the authors free of charge. The program requires the user's observational data to be saved in TSD format. The user is simply required to specify the location of the data file(s) and to enter a given and a target behavior code. The program then outputs profile data and associated profile scores. The program runs on an IBM-compatible PC under Windows.

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NOTES

1. These data and the data example presented later in the paper have been adapted from Repp et al., 1989, *Behavioral Assessment*, **11**, p. 254. Copyright 1989 by Elsevier Science. Adapted by permission.
2. We are grateful to Roger Bakeman for pointing this out.
3. A modified version of the method first appeared in Hall and Oliver (1992).
4. The first and last occurrences of X are not included in the analysis because the number of time units from a previous occurrence of X to the first occurrence of X in the data and from last occurrence of X in the data to a following occurrence of X are undetermined due to session boundaries.
5. We thank Roger Bakeman for his contribution in defining the time periods.

APPENDIX

Modified Example Data and Commands Issued to Conduct the “Conditional Probability” Analysis Using GSEQ

```

Timed PREX X FOLX Y;
,l
PREX,5-14) X,15-22) FOLX,23-32) Y,23-39) PREX,73-82) X,83-88) FOLX,89-90) PREX,90-91) X,92-101)
Y,100-116) FOLX,102-111) PREX,134-143) X,144-150) Y,150-165) FOLX,151-160) PREX,171-180)
X,181-186) Y,183-204) FOLX,187-196) PREX,240-249) X,250-256) Y,255-268) FOLX,257-266)
PREX,292-301) X,302-311) FOLX,312-313) PREX,314-315) X,316-345) Y,320-336) FOLX,346-355)
PREX,355-364) X,365-372) Y,368-386) FOLX,373-382) PREX,394-403) X,404-411) Y,408-425)
FOLX,412-421) PREX,447-456) X,457-470) FOLX,471-480) Y,482-487) PREX,498-507) X,508-513)
FOLX,514-523) Y,514-532)
,547)/

File “xy”;
Window PREY = (Y-10,(Y-1;
Window FOLY = Y)+1,Y)+10;
Stats CONP YULQ;
Target Y &;
Given PREX &;
Target Y &;
Given X &;
Target Y &;
Given FOLX &;
Target X &;
Given PREY &;
Target X &;
Given Y &;
Target X &;
Given FOLY &;
End;

```

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