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Observational Analysis of the Organization of On-Task Behavior in the Classroom Using Complementary Data Analysis

Carlos Santoyo[1*], Gudberg K. Jonsson[2], M. Teresa Anguera[3] and José Antonio López-López[4]

1 Universidad Nacional Autónoma de México.Ciudad de México (México).
2 Iceland University.Rejkyavik (Iceland).
3 Universidad de Barcelona.Barcelona (Spain).
4 Universidad de Málaga.Málaga (Spain).

Título: Análisis observacional de la organización del comportamiento en la tarea en el aula utilizando complementariedad de análisis de datos
Resumen: El objetivo de este estudio es analizar la organización de la actividad académica en el aula de clase. Cuatro técnicas de análisis de datos utilizadas en metodología observacional –detección de *T-Patterns*, análisis secuencial de retardos, análisis de tendencias, y análisis de coordenadas polares- han permitido estudiar como los escolares de Primaria distribuyen sus actividades en el aula. De forma específica, se pretendía detectar y explorar las relaciones entre las conductas relativas al trabajo académico y diferentes categorías de interacción social respecto al uso del tiempo en el contexto de la vida cotidiana en el aula. El estudio se llevó a cabo mediante el instrumento de observación SOC-IS, focalizado en la interacción social, y se utilizaron los programas informáticos THEME (versión 6, Edu), SDIS-GSEQ (versión 4.1.2), HOISAN (versión 1.6), y STATGRAPHICS (versión 16). Se describen los T-Patterns, patrones de conducta, tendencias y vectores obtenidos, sí como las implicaciones metodológicas de la estrategia propuesta.
Palabras clave: Metodología observacional; interacción social; persistencia académica; detección de T-Patterns; análisis secuencial de retardos; análisis de tendencias; análisis de coordenadas polares.

Abstract: The aim of this study was to analyze the organization of on-task behavior in the classroom. Four observational methodology techniques—T-pattern detection, lag sequential analysis, trend analysis, and polar coordinate analysis—were used to study the organization of on-task and off-task behavioral patterns during class time in a primary school setting. The specific objective was to detect and explore relationships between on-task behavior and different social interaction categories in relation to the actual distribution of activities in a real-life classroom setting. The study was conducted using the behavioral observation system for social interaction SOC-IS and the software programs Theme (version 6, Edu), SDIS-GSEQ (version 4.1.2), HOISAN (version 1.6), and STATGRAPHICS (version 6). We describe the results obtained for the four techniques and discuss the methodological implications of combining complementary techniques in a single study.
Key words: Observational methodology; social interaction; academic engagement; T-pattern; lag sequential analysis; trend analysis; polar coordinates.

Introduction

In this paper, we analyze the organization of behavioral patterns of children in a primary school classroom by identifying behaviors that favor or interfere with on-task activity during academic instruction.

The Teaching and Learning International Survey (TALIS) is a cross-country survey conducted by the Organization for Economic Co-operation and Development (OECD) to investigate how, among other things, teachers distribute their time in the classroom, which is, logically, related to time spent by children on academic activities (TALIS, 2013). The survey showed that one of four teachers spend at least 30% of their time dealing with disruptive behavior, interruptions, and administrative tasks. In Mexico, teachers reported that they spent just 69% of their classroom time on learning activities (vs 80% in other OECD countries). Secondary school teachers, in turn, reported spending 345 hours a year resolving student conflicts, imposing order, and doing paperwork, which is a considerable amount of time that could be spent on instruction. Findings such as these are cause for concern and of particular relevance in several OECD countries, especially in terms of the implications for public policies in Latin America (Martinic, 2015). While information of this type seems crucial for education planning and evaluation purposes, research in this area to date has focused mainly on sources of indirect data rather than on the use of direct observation to investigate real-time activity patterns of teachers, and equally importantly, children in the classroom.

The present study analyzes streams of behavior exhibited by children performing academic tasks in the classroom. We employed an observational methodology design to gather information on the organization of behavioral patterns in a primary school classroom. Observational methodology has emerged in recent years as a highly effective and useful technique for analyzing behaviors and events in a wide range of fields. Adequate use of this scientific method provides a rigorous analytical framework for addressing specific research questions using one or more research designs inherent to observational methodology.

Most observational methodology studies to date have analyzed data from a single perspective, i.e., using a single method, although there is growing interest in the combined use of complementary methods to unlock the informative and predictive power hidden within large volumes of data collected using direct observation methods (Tarragó, Iglesias, Lapresa, & Anguera, 2016; Tarragó, Iglesias, Lapresa, Anguera, Ruiz-Sanchis, & Arana, in press). Such approaches can only contribute to enhancing substantive and methodological richness, and consequently improving our understanding and interpretation of empirical evidence (data). Although each method has its own characteristics and purpose,

*** Correspondence address [Dirección para correspondencia]:**
Carlos Santoyo V., Facultad de Psicología, División de Investigación y Posgrado, Edif. D, cub.120, Av. Universidad 3304, Col. Universidad Nacional Autónoma de México, Deleg. Coyoacán, CP 04510, Ciudad de México (México). E-mail: carsan@unam.mx

the "cross-fertilization" of methods is likely to provide additional and complementary insights into given research questions. Furthermore, the combination of distinct technical and methodological approaches provides a broad perspective from which to contemplate different angles and aspects of the same question.

For the purpose of the present study, it was necessary to identify and analyze the dynamics of behaviors and behavioral patterns within and related to on-task academic activities. In situ observation of on-task behavior as an indicator of classroom motivation and social ecology (Heward, 1994) or of frequency of activity interruption (Santoyo, 2010) is an adequate strategy for this purpose. Previous studies using a similar approach have shown the high level of flexibility offered by observational methodology in the classroom (Santoyo & Anguera, 1992; Otero & Haut, 2016; Razo, 2015; Santoyo, Fabián, & Espinosa, 2000).

Earlier studies have analyzed control exerted by teachers over time spent on academic tasks by students and the effects of on-task behavior and contingent teacher attention on academic engagement (Abramowitz, O'Leary & Futtersak, 1988; Berk & Landau, 1993; Heller & White, 1975). The effects of reinforcement strategies on academic activity have also been analyzed (Martens, 1990; Martens, Halperin, Rummel, & Kilpatrick, 1990; Santoyo et al, 2000). Forms and means of teacher-student interactions can be described by the matching law (Torres, 2012; Delgado, 2013), and two very recent studies have shown that reinforcement interventions focused on self-regulation can improve on-task behavior (Norris, 2016; Slattery, Crosland, & Iovannone, 2016). However, it is also necessary to collect information on classroom events that occur that influence the development of diverse behavioral patterns, and in particular the behavior stream of individual students and their social interaction with peers.

One way of studying behavioral patterns in the classroom is to analyze the frequency of transition from one behavior to the next. While many children typically "jump" from one activity to another, others are relatively persistent when it comes to task completion. Previous studies of children at primary schools, for example, have shown that most children change activities about three or four times every minute, and that on average they dedicate just 25% to 30% of available class time to academic activities. In other words, around three-quarters of instruction time is spent on non-academic and social activities (Santoyo et al., 2000; Santoyo, Morales, Colmenares, & Figueroa, 2007). Similar results have been reported for other classroom settings (Razo, 2015). It is therefore important not only to determine what favors on-task behavior and how long children spend on task, but also to assess behavioral patterns over a period of time.

To address these questions, we built on former research involving archival data (Elder, Pavalko, & Clipp, 1993) and defined new research questions based on information compiled from the databases of the Longitudinal Coyoacán Study (Santoyo, 2007; Santoyo, Espinosa, & Bachá, 1994, 1996; Santoyo & Colmenares, 2012). The availability of consistent, robust, and reliable information permits the formulation of new questions that can be answered with adequately collected data.

The aim of this study was to use four complementary observational methodology techniques to analyze relationships between episodes of on-task behavior and different social interaction categories and to transfer our results to the classroom in order to better understand the development of student behavioral patterns.

Method

Design

We undertook an observational methodology study, which is appropriate for analyzing spontaneous behavior in a natural setting. The specific design used was an I/F/M design (Anguera, Blanco-Villaseñor, & Losada, 2001), where I refers to idiographic (analysis of data for 28 students although in this study we focus on just one student), F refers to follow-up (data collected over eight sessions), and M refers to multidimensional (assessment of multiple levels of response). The multidimensional nature of the study influenced subsequent decisions regarding the content of the observation instrument (Anguera, Magnusson, & Jonsson, 2007) and the nature of the data (Bakeman, 1978).

Participants

We contemplated both molar and molecular views of the behaviors analyzed. From the molar perspective, we briefly described the overall use of classroom time by 28 first-year primary school students (18 boys and 10 girls) in a public school in Mexico City, Mexico. From the molecular perspective we focused on the individual behaviors of one student in particular (the target student, coded as *fdo1f*) as a case study. Details of the sampling method and other aspects of the Longitudinal Coyoacán Study are described elsewhere (Santoyo & Espinosa, 2006; Santoyo, 2007). The research project was approved by an ethics committee at the university of the first author and the study was approved by the school authorities. Informed consent was obtained from all the children's parents.

Instruments

1. Observation instrument. The observation instrument used to analyze and code the behaviors of the children was the behavioral observation system for social interaction, known as SOC-IS, according to its acronym in Spanish (Santoyo et al, 1994). The instrument is formed by five dimensions or criteria (Classmate, Initiation, Episode, Task, Area), each of which is broken down into a system of exhaustive, mutually exclusive categories (Table 1). SOC-IS is a valid, reliable, flexible, and viable instrument with a long track record and guarantees of quality, including between-observer agreement rates of over 0.8 (Bakeman & Gottman, 1986) and generalizability rates of over 0.9 for trained observers, individuals (sample representativeness), and number of sessions (Espinosa, Blanco-Villaseñor, & Santoyo, 2006).

Table 1. Behavioral observation system for social interaction SOC-IS (Santoyo et al, 1994). Behavior categories used in the present study with corresponding codes and definitions. The category *eac* represents on-task behavior while the other categories represent off-task behavior.

Category	Code	Definition
Academic activity (on-task behavior)	*eac*	Behavior displayed by the target child in response to specific instructions from the teacher in relation to the learning goal at the time. May involve contact with material depending on the task.
Emission	*eiep*	Physical and/or verbal behavior that is directed by the target student towards others and is not immediately preceded by an interaction initiated by another child. The code of the child towards whom the action is directed is noted down.
Reception	*eipr*	Physical and/or verbal behavior initiated by another student that is directed at the target child and not immediately preceded by any social behavior by the target child. The peer's code is noted down.
Negative emission	*eisne*	Coercive physical and/or verbal behavior that is directed by the target child towards another child and is not immediately preceded by any initiative from the other child. The code of the child towards whom the action is directed noted down.
Social interaction	*Esp*	Simultaneous or successive physical and/or verbal behavior targeting the target child or other children in which there is mutual dependence. The letter 'e' following *Esp* (*Espe*) indicates initiation by the target child while the letter 'r' (*Espr*) indicates initiation by a peer.
Negative social interaction	*Esn*	Simultaneous or successive coercive physical and/or verbal behavior targeting the target child or other children in which there is mutual dependence. The letter 'e' following *Esn* (*Esne*) indicates initiation by the target child, while the letter 'r' (*Esnr*) indicates initiation by a peer.
Negative reception	*eisnr*	Coercive physical and/or verbal behavior that is directed by another child towards the target child and is not immediately preceded by any initiative from the target child. The peer's code is noted down.
Free activity	*eal*	Behavior displayed by target child involving academic material selected by the teacher, but without a specific learning goal. It involves different levels of contact with the material depending on the needs of the child.
Isolated play	*eja*	Behavior displayed by the target child involving objects and/or toys, without the participation of others. The type of play is identified by what the child is doing and/or what rules he is applying.
Parallel play	*ejp*	Behavior displayed by the target child involving objects and/or toys that occur at the same time as and independently of the participation of others in accordance with rules established by the group.
Other responses	*eor*	Behavior displayed by the target child that is not covered by the other categories in SOC-IS.
Group play initiated by target child	*ejge*	Play situation initiated by the target child that establishes mutually dependent interactions between the target child and another child in accordance with the rules of the game; it may or may not involve contact with objects and/or toys.
Group play initiated by a peer	*ejgr*	Play situation initiated by another child that establishes mutually dependent interactions between the target child and another in accordance with the rules of the game; it may or may not involve contact with objects and/or toys.

Characteristics of SOC-IS:

a) Numerous exhaustive and mutually exclusive behavioral categories, with the following response criteria: Episode, Initiation, and Area
b) Representative category system based on actions performed by children in the classroom (academic tasks, social interaction, group play, individual play, non-academic behavior)
c) Recording of event-based data based on events that occur within predefined intervals
d) Detection of direction of social interaction to identify initiator of action

2. *Recording instrument*:

The freely available software program SDIS-GSEQ version 4.1.2. (Bakeman & Quera, 1996, 2011) [*http://www.ub.es/comporta/sg/sg_s_download.htm*], loaded with SOC-IS, was used to analyze and code the video footage of the sessions via time-based data.

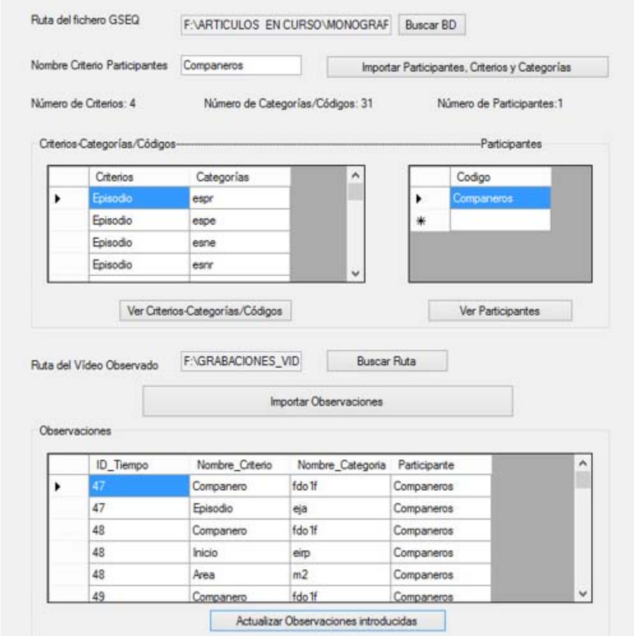
3. Data analysis instruments. To meet the study objective, which required the use of four analytical techniques, we used the following four software programs:

a. THEME 6 Edu (Magnuson, 1996, 2000, 2005) for the T-Pattern analysis (free software program). This software is free. Table 2 shows a screenshot of the data loaded into THEME.
b. SDIS-GSEQ version 4.1.2. (Bakeman & Quera, 1996, 2011) [*http://www.ub.es/comporta/sg/sg_s_download.htm*] to calculate the adjusted residuals needed to analyze sequential behaviors by lag sequential analysis (free software program)
c. HOISAN version 1.6 (Hernández-Mendo, López-López, Castellano, Morales-Sánchez, & Pastrana, 2012; Hernández-Mendo et al., 2014) to calculate polar coordinates according to the original proposal of Sackett (1980) and the concept of genuine retrospectivity proposed by Anguera (1997). This software program is also free and displays results in the form of polar coordinate maps.

Table 3 shows a screenshot of the observation instrument SOC-IS loaded into HOISAN.

d. STATGRAPHICS version 16 to generate linear regression equations and display the corresponding trends in graph format.

Table 2. Screenshot from HOISAN showing a sample of record using SOC-IS observation instrument.



Procedure

Eight 15-minute classroom sessions were analyzed and coded in situ by trained observers in SDIS-GSEQ using timed data (type IV data according to the data types described by Bakeman [1978]) derived from within-session observational sampling using 5-second intervals.

Datasets with interobserver agreement levels of less than 80% were eliminated and a new dataset was generated. Interobserver agreement (kappa statistic) for the behaviors of the target child was 0.94 (Cohen, 1960, 1968). This analysis was performed on the same day as the field session, following coding of the data.

Results

In this section we investigate the convergence between the four data analysis techniques used to investigate the relationships between on-task behavior (*eac* category in SOC-IS) and the other social interaction categories in the instrument. We chose the *eac* category to represent on-task behavior as a key indicator of academic motivation and the impact of teacher-led activities. In studies of the use of class time, it is obviously important to analyze how much time children spend on instructional practices. Our study differs from previously cited studies in that it provides information on specific interactions

Table 3. Screenshot from Theme v.6 Edu showing the SOC-IS observation instrument. The column "area" shows the students' desks, where m1 is the target student's desk and m2, m3, and m4 are the desks assigned to other students defined by proximity to m1. The "missing" column shows the codes corresponding to the other students in the group who may potentially interact with the target student.

episodio	inicio	area	companero	missing
espr	eirp	m1	pr	alf1f
espe	eiep	m2	fdo1f	and1f
esne	eien	m3		axe1f
esnr	eirn	m4		edg1f
ejge		out		lau1f
ejgr		pat1		pata1f
eac		pat2		tan1f
eor		pas1		lui1f
eal		pas2		rau1f
eja		esc		fera1c
ejp		bebe		jim1c
		llan		ric1f
		l		ale1f
		ports		oba1f
				ken1f
				otro
				clap1f
				jai1f
				lizg1f
				mich1f
				jor1f

that are generally broadly classified as off-task activities, thereby providing insights into how a specific child and his peers contribute to the persistence of academic engagement in the classroom.

At the molar level, the 28 children switched behaviors on average three or four times a minute and 25% of the transitions were in response to an interaction initiated by another child. The children generally spent less than 30 seconds on task at a time, and the likelihood of switching from an on-task to an off-task activity was linearly dependent on the time spent on the first task. In other words, the longer the time spent on *eac*, the less likely the child was to abandon the task and vice versa. For more information on the molar distribution of behavioral transitions we recommend consulting Santoyo (2006).

Although we analyzed diachronic relationships between *eac* and the other categories for the 28 children over eight sessions, in this next section, we focus on the results obtained for the target student *fdo1f*. The boy spent just 19% of the total class time recorded on *eac*; the rest of his time was divided between social interaction (43%) and other activities (38%). The specific behavioral patterns detected using each of the four techniques are described below.

T-Pattern detection

The first analysis was T-pattern detection, which is used to identify hidden patterns within sequential datasets (Magnusson, 1996, 2000, 2005). To meet the requirements of the technique and the software program (Theme v. 6 Edu), we prepared the vvt.vvt file corresponding to the observation instrument and the respective .txt data files, arranged in a single block. A screenshot from the program is shown in Figure 1.

For the first analysis we search for patterns occurring in at least 50 % of the observational files, using a significance level of $p < .05$. The pattern detection resulted in 133 different T-patterns. To narrow down the selection using all the calculations for the target student, we prioritized T-patterns first according to their level of statistical significance and second according to their relationship with the aims of the study (i.e. T-patterns related to the performance of academic tasks in the classroom, i.e., the connection between *eac* and *m1)*. The category *m1* refers to the place assigned to the student in the classroom, i.e., his desk. Table 3 shows all the areas considered for the general study, but for the purpose of this analysis, we used *m1* to investigate whether the target student interacted with his peers or displayed *eor* behavior away from his desk.

dataname	time	eventtype
test	0	:
test	14	fdo1f,eor,eja,out
test	19	fdo1f,alf1f,eirp,m2
test	24	fdo1f,eor,out
test	34	fdo1f,lau1f,eiep,ejge,m1
test	59	fdo1f,eor,m1
test	94	fdo1f,eac,m1
test	99	fdo1f,eor,m1
test	134	fdo1f,eac,m1
test	139	fdo1f,eor,m1
test	144	fdo1f,eiep,m1
test	219	fdo1f,eor,out
test	224	fdo1f,eiep,out
test	234	fdo1f,eor,out
test	254	fdo1f,alf1f,eiep,ejge,m2
test	264	fdo1f,alf1f,eirn,esnr,m2
test	294	fdo1f,eor,out
test	299	fdo1f,edg1f,eirp,espr,m3
test	389	fdo1f,eor,out
test	409	fdo1f,eac,m1
test	454	fdo1f,axe1f,eiep,espe,m2
test	479	fdo1f,eor,out
test	489	fdo1f,tan1f,eiep,espe,m2

Figure 1. Screenshot from Theme v.6 Edu showing a sample of the T-patterns retrieved from the dataset. The codes correspond to the codes in the SOC-IS observation instrument and each row (event-type) shows the co-occurrence of codes (one for each of the dimensions of the instrument). The second column, time, shows the duration of each co-occurrence in frames. In rows showing event-types in which a peer intervenes, the peer's code is shown immediately after the target student's code, *fdo1f*.

We focused our analysis on T-pattern #1, the most complex pattern found to occur in half of the observation files, and T-pattern #129, which was the last of the 133 T-patterns containing *eac* and occurring in over half of the observation files (Figures 2 and 3). *m1* appeared in all the branches of the tree diagrams featuring *eac*, showing the strong association between the two categories.

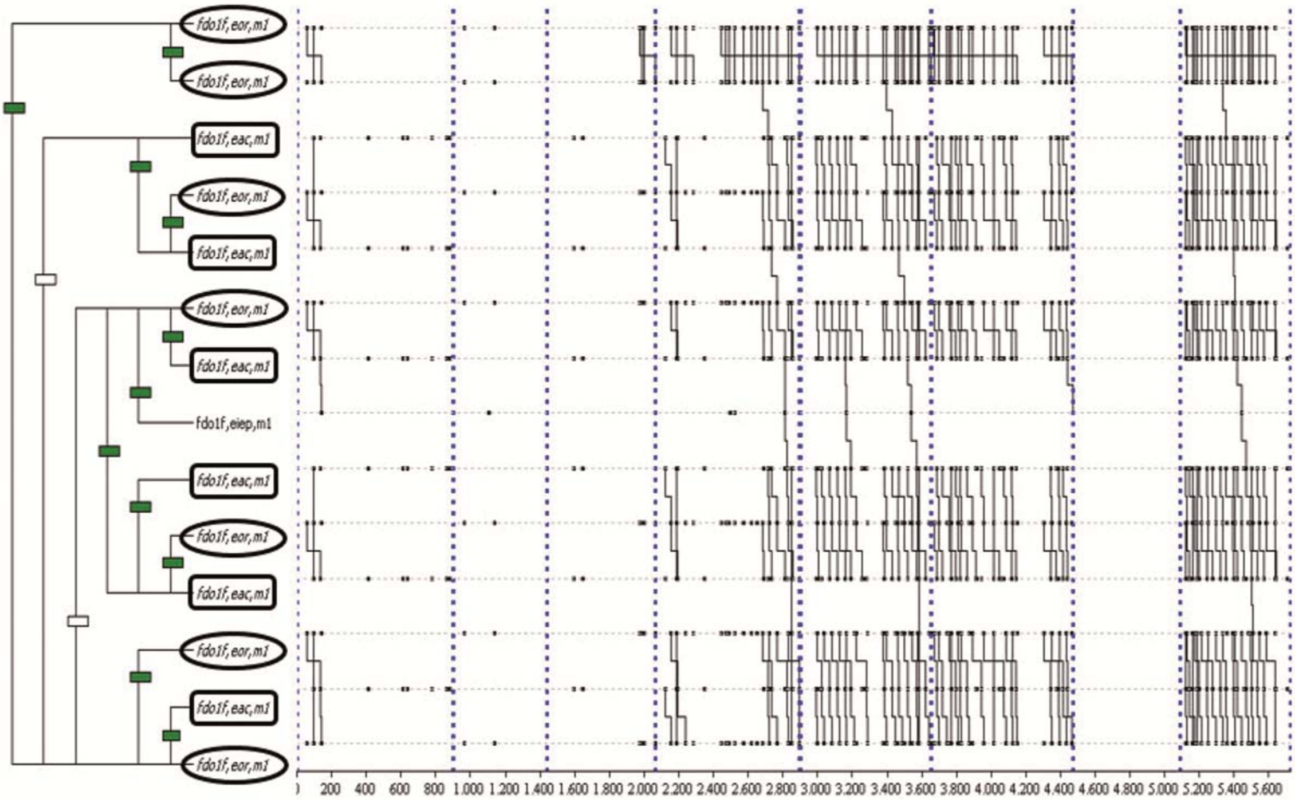


Figure 2. T-pattern #1 (level of significance $p < .05$ and occurrences in 50% of observational records) showing relevant results: a) there is an almost perfect alternation in all the branches of the tree diagram between the occurrence of *eac* (on-task behavior) and *eor* (off-task), providing key insights that help to better understand the organization of behaviors by children in a classroom setting; b) in all the branches of the tree diagram containing *eac*, there is a connection between *eac* and *m1* for the target student; and c) in all the branches of the tree diagram containing *eor*, there is a connection between *eor* and *m1*. The connections between *eac* and *m1* are shown in a rectangle while those between *eor* and *m1* are shown in a ellipse.

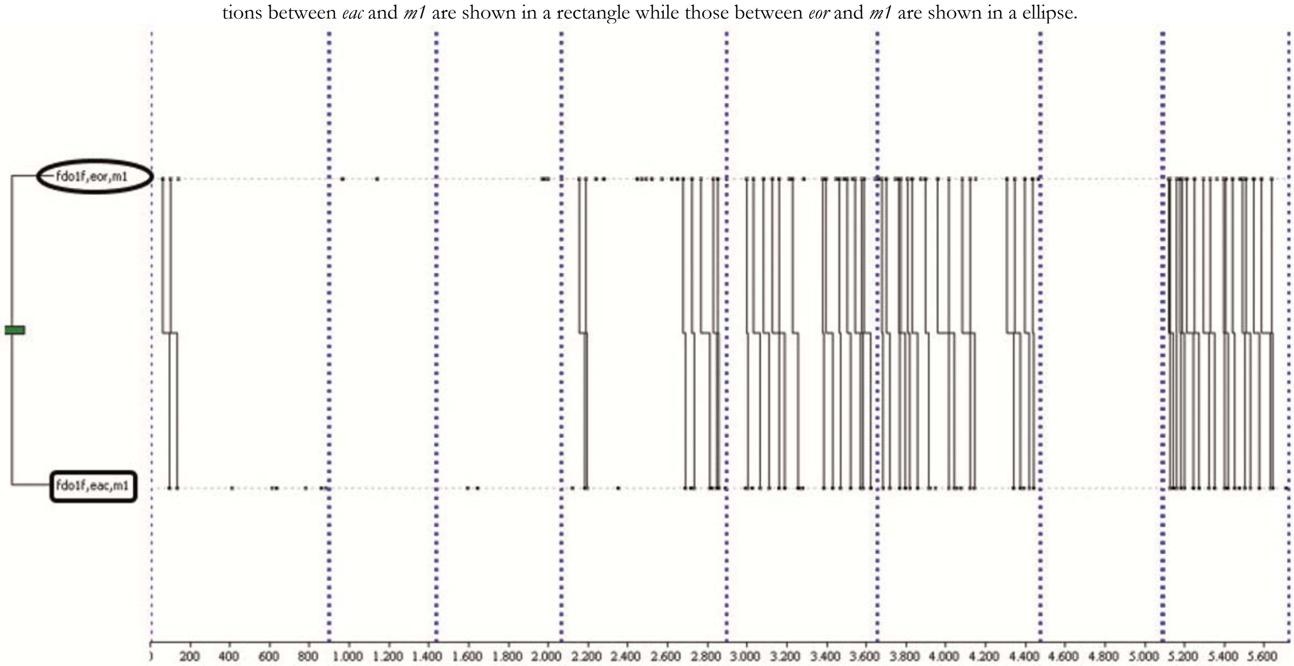


Figure 3. T-pattern #129 (significance level of $p < .05$ and occurrences in 50% of observational records). This T-pattern is practically the simplest of all the patterns retrieved (there are 133 in total). Note how the connection between *eac* and *m1* is maintained for the target student *fdo1f* in the only branch of tree diagram containing *eac*. The connection with *m1* is also maintained in the only branch containing *eor*. The connection between *eac* and *m1* are shown in a rectangle while that between *eor* and *m1* is shown in a ellipse.

When we increased the statistical significance requirements (to a level of p < .005 and a minimum occurrence setting of 50% of the observational records), we found 15 T-patterns, but the connection between *eac* and *m1* was retained (see T-pattern 1 with the strictest parameter requirements in Figure 4).

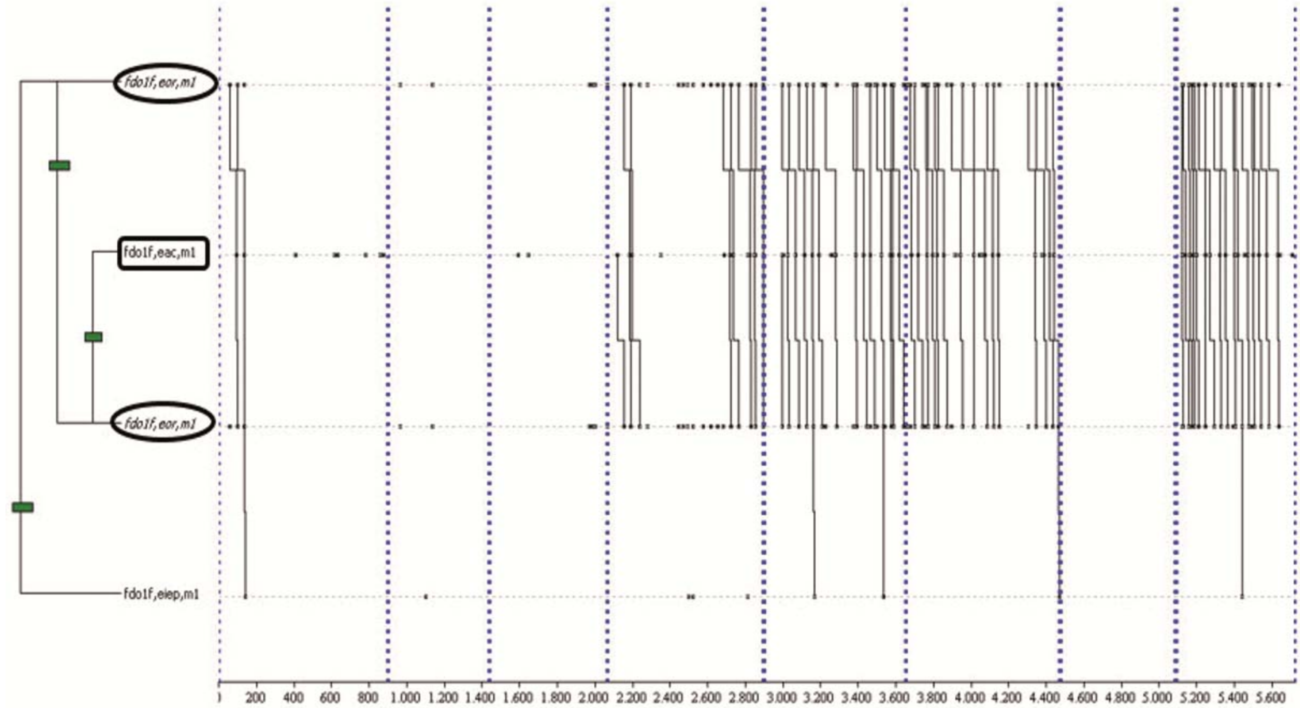


Figure 4. T pattern #1 with stricter statistical requirements than in Figures 2 and 3 (significance level $p < .005$ and occurrences in 50% of observational records). The pattern shows the connection between *eac* and *m1* for the target student *fdo1f* in the only branch of the tree diagram containing *eac*. In the two branches of the tree diagram containing *eor*, there is also a connection between *eor* and *m1* for the target student. The connection between *eac* and *m1* are shown in a rectangle while the connections between *eor* and *m1* are shown in a ellipse.

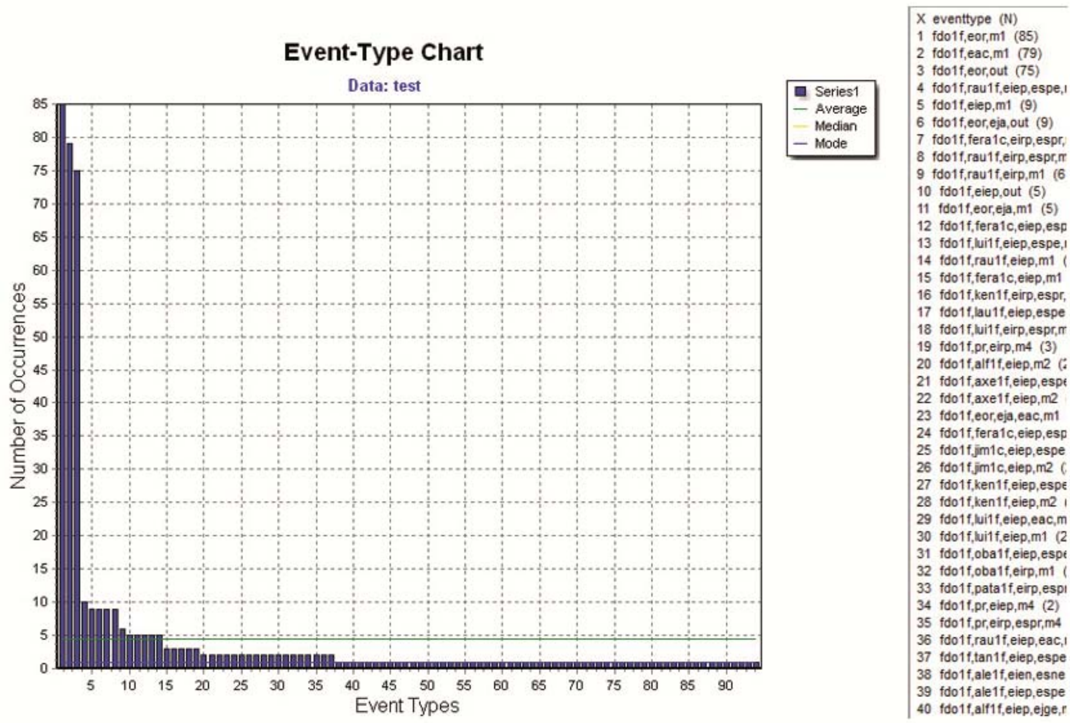


Figure 5. Frequencies of event-types showing how *eac* is only connected with *m1* for the target student *fdof1*. Likewise, *eor* is connected with *m1* and *out* for the same student.

However, in order to explore synergies between the four methods, we were interested not only in determining the extent to which *eac* was statistically associated with certain categories but also in identifying the categories with which it was not associated. On observing the frequencies of the different event-types for the target student *fdo1f* (see Figure 5), we found that *eac* was only connected to *m1*. In other words, while performing the classroom task (*eac*), the student exhibited no connections with Initiation, Area (except for *m1*), or missing categories. Another interesting observation is the high distribution of *eor* (off-task behavior), as this reflects the motivational competition that exists between on-task and off-task behavior.

In this analysis the category *eor* was also closely associated with *m1*, indicating that the student did not move from his desk while alternating between on-task and off-task activities.

In the next section, we investigate events that triggered *eor* (e.g., *eiep*) using the other techniques with the ultimate aim of achieving valuable, complementary insights.

Lag sequential analysis

The first technique analyzed in this section is lag sequential analysis (Bakeman, 1978; Bakeman & Quera, 1996, 2011; Sackett, 1978, 1979; Bakeman & Gottman, 1986), which was performed using SDIS-GSEQ, GSEQ5, and HOISAN.

The SDIS-GSEQ algorithm compares conditional and unconditional probabilities related to behaviors that occur in the form of transition frequencies after the criterion behavior (or given behavior as it is known in SDIS-GSEQ). The given behavior is established according to the needs of each study. Considering its relevance in our study, the *eac* category was established as both the criterion and the conditional behavior. Adjusted residuals for the positive lags R1 to R5 were calculated using the binomial test and the correction proposed by Allison and Liker (1982).

Separate datasets were generated for each of the eight sessions. Data were entered using the timed-event data option (type IV data). The resulting SDS files were then converted to MDS files using the GSEQ compiler. Lag sequential analysis was performed using the GSQ file (Table 4).

Using the results of this analysis (OUT file), we identified the occurrence of both excitatory or activating behavioral patterns ($Res_{adjust} > 1.96$, for $p < .05$) and inhibitory behavioral patterns ($Res_{adjust} < -1.96$, for $p < .05$) (Table 1).

Table 4. Significant adjusted residuals corresponding to the *eac* category as both the criterion and conditional behavior in the lag sequential analysis (selected from among all the categories), with consideration of lags R1 to R5. Activating relationships are shown in normal font and inhibitory relationships in italics. Relationships with the *eac* category are shown in bold capital letters. All the social interaction categories (episodes and initiation) were considered in the lag sequential analysis.

	R1	R2	R3	R4	R5
eiep	***EAC* (-8.65)**	***EAC*(-7.83)**	***EAC*(-7.01)**	***EAC*(-6.19)**	***EAC*(-6.29)**
eirp	***EAC*(-4.59)**	***EAC*(-3.71)**	***EAC*(-2.83)**		
espr	***EAC*(-14.50)**	***EAC*(-14.01)**	***EAC*(-13.52)**	***EAC*(-13.03)**	***EAC*(-12.69)**
espe	***EAC*(-16.53)**	***EAC*(-16.26)**	***EAC*(-15.99)**	***EAC*(-15.71)**	***EAC*(-15.45)**
ejge	***EAC*(-8.71)**	***EAC*(-8.72)**	***EAC*(-8.72)**	***EAC*(-8.73)**	***EAC*(-8.70)**
ejgr	***EAC*(-3.54)**	***EAC*(-3.54)**	***EAC*(-3.54)**	***EAC*(-3.55)**	***EAC*(-3.52)**
EAC	***EAC*(79.75)** *espr (-14.51)* *espe (-16.54)* *ejge (-8.71)* *ejgr (-3.59)* *eor (-42.60)* *eirp (-4.63)* *eiep (-8.61)*	**EAC (74.78)** *espr (-13.70)* *espe (-15.63)* *ejge (-8.72)* *ejgr (-3.59)* *eor (-39.80)* *eirp (-4.34)* *eiep (-7.49)*	**EAC (69.81)** *espr (-12.89)* *espe (-14.72)* *ejge (-8.73)* *ejgr (-3.59)* *eor (-36.99)* *eirp (-4.05)* *eiep (-6.38)*	**EAC (64.83)** *espr (-12.08)* *espe (-13.81)* *ejge (-8.74)* *ejgr (-3.59)* *eor (-34.18)* *eirp (-3.76)* *eiep (-5.26)*	***EAC*(61.01)** *espr (-11.44)* *espe (-12.92)* *ejge (-8.70)* *ejgr (-3.53)* *eor (-31.45)* *eirp (-4.04)* *eiep (-5.21)*
eor	***EAC*(-42.63)**	***EAC*(-39,24)**	***EAC*(-35.85)**	***EAC*(-32.46)**	***EAC*(-29.17)**

The high values obtained for *eac* as both the criterion and conditional behavior indicates that the task is self-sustained, which is further supported by the fact that it has a statistically significant inhibitory relationship with *espr, espe, ejge, ejgr, eor, eirp,* and *eiep*. As shown by Table 2 *eiep, eirp, espr, espe, ejge, ejgr*, and *eor* also had a significant inhibitory relationship with *eac*.

To explore the connection between *eac* and *m1* using lag sequential analysis, we analyzed lag 0, which corresponds to concurrent events (Table 5).

Table 5. Adjusted residuals table showing statistically significant co-occurrences between *eac* and *m1* and the inhibitory relationship between *eor* and *m1* and *m2*.

Retardo 0. RSAJ. Residuos ajustados

Dados	Condicionados m1	m2	m3	m4	out	pat1	pat2	pas1
espr	-1.25:	0.84:	3.41:	3.41:	-1.67:	0.00:	0.00:	0.00
espe	-1.25:	4.11:	-0.30:	-0.30:	-1.67:	0.00:	0.00:	0.00
esne	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00
esnr	-0.70:	2.30:	-0.17:	-0.17:	-0.93:	0.00:	0.00:	0.00
ejge	0.55:	1.33:	-0.24:	-0.24:	-1.34:	0.00:	0.00:	0.00
ejgr	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00
eac	4.61	-1.41:	-0.53:	-0.53:	-2.95:	0.00:	0.00:	0.00
eor	-2.46:	-2.90:	-1.10:	-1.10:	5.17:	0.00:	0.00:	0.00
eal	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00
eja	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00
ejp	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00:	0.00

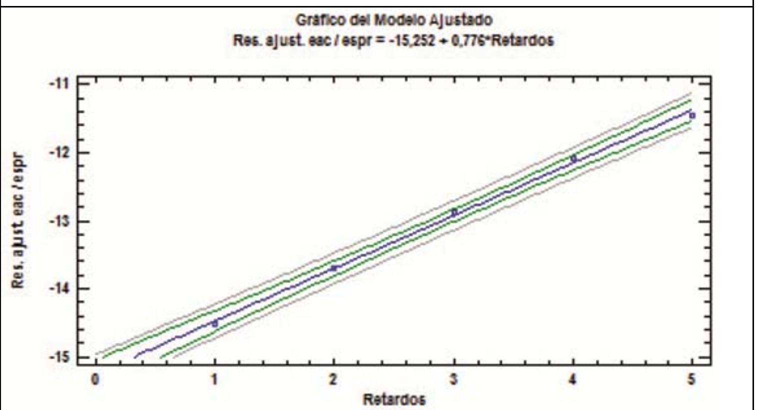
As seen, the adjusted residual was 4.61, indicating a strongly significant association between the two categories. The negative connection between *eor* and *m1* is also noteworthy, as it shows that off-task behavior also occurs away from the student's desk, complementing findings from the first analysis.

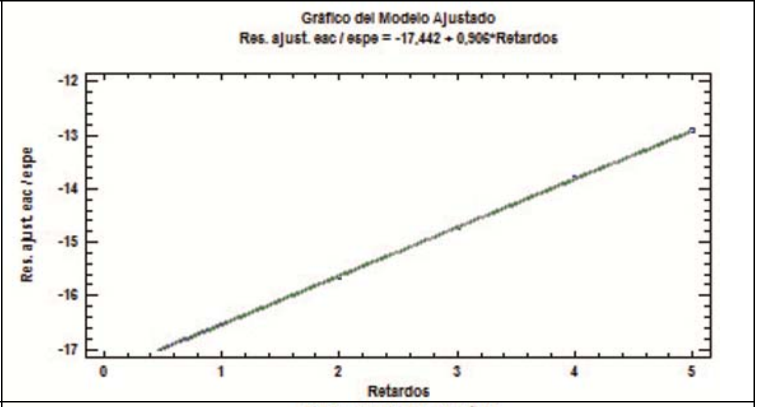
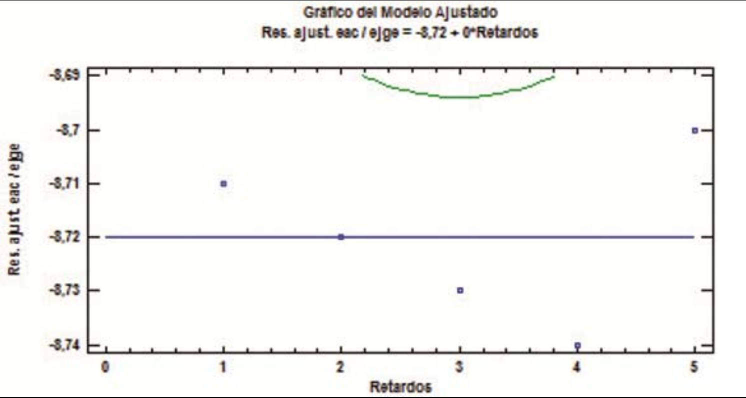
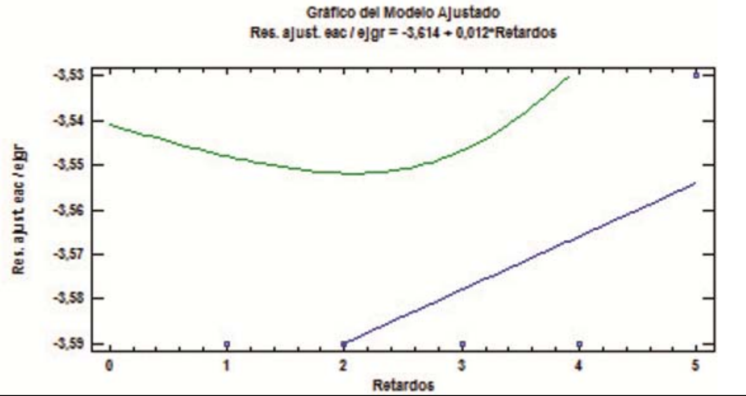
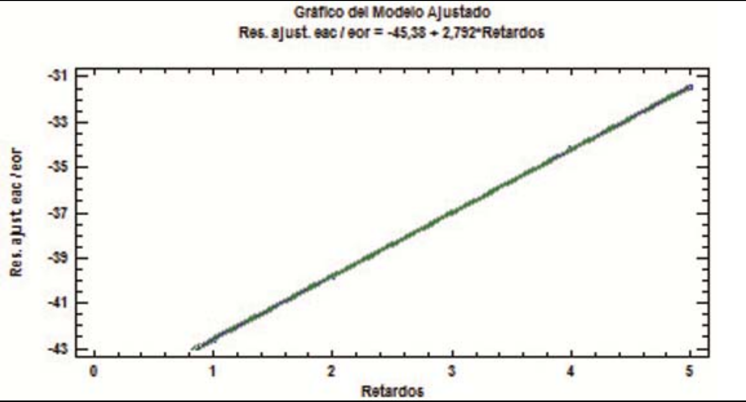
Trend analysis

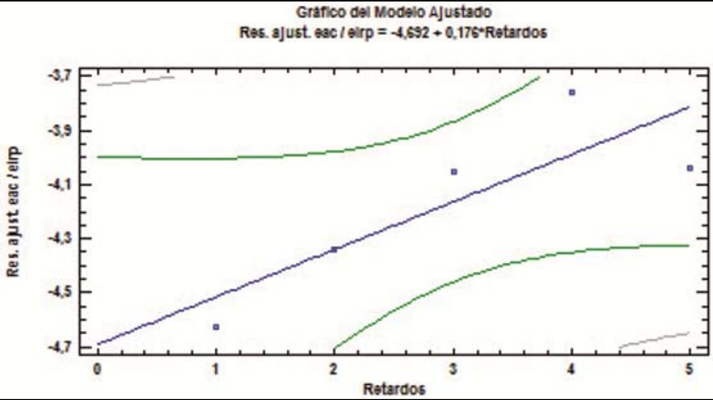
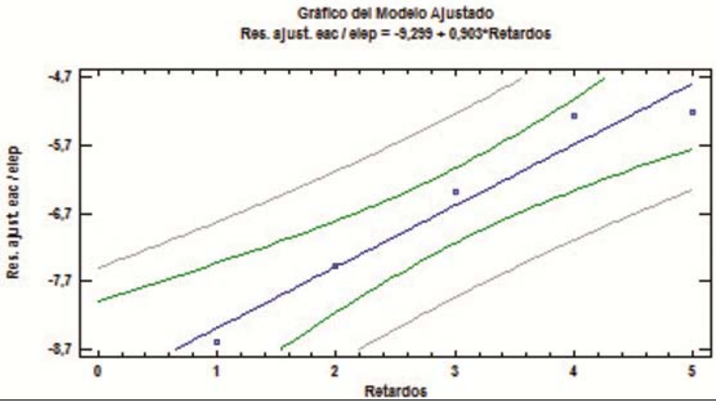
Using the adjusted residuals obtained in the lag sequential analysis, we applied trend analysis to assess the extent to which the relationships connecting *eac* with the other categories varied across the different lags analyzed.

Using the adjusted residuals available for each of the positive lags, R1 to R5 (Table 3), linear regression equations were generated in STATGRAPHICS and the resulting trends were displayed as graphs. As mentioned above, the *eac* category was established as both the criterion (Table 6) and the conditional behavior (Table 7).

Table 6. Regression equation results and adjusted residual graphs (lag sequential analysis), with the *eac* category as the criterion behavior.
Gráfico del Modelo Ajustado = Adjusted Model Graph.

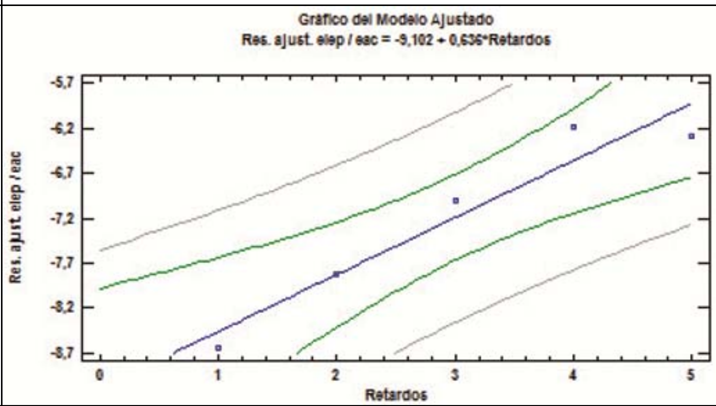
Target behavior	Regression equation	*p*	Trend
espr	Adjusted residual *eac* / *espr* = -15.252 + 0.776*Lags	**0.0000*** **	

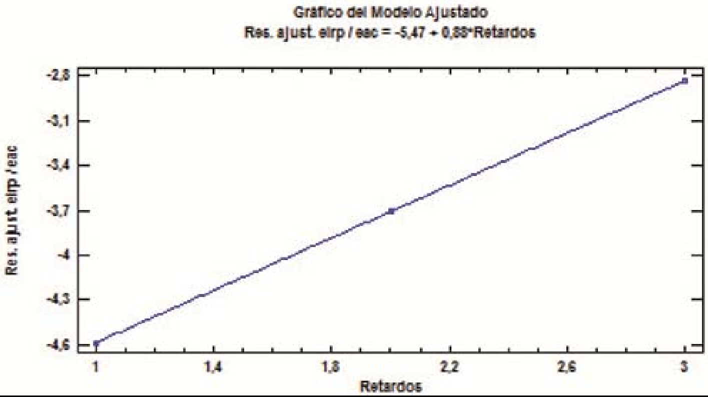
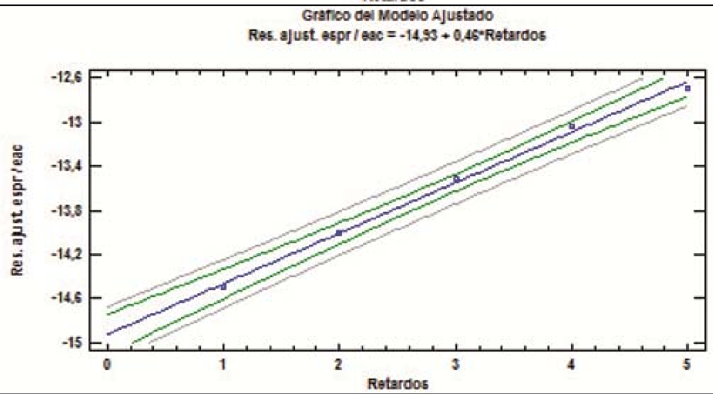
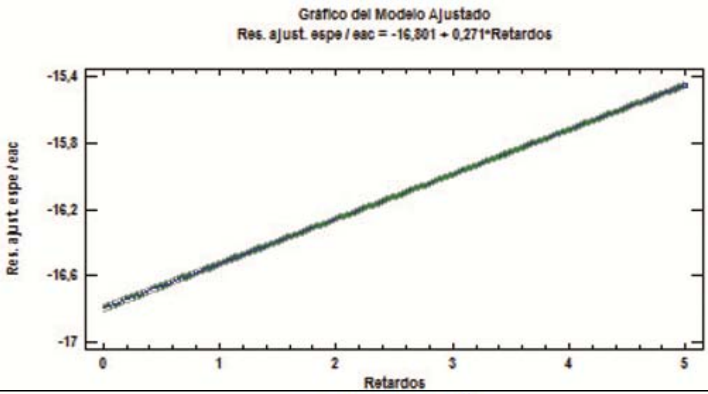
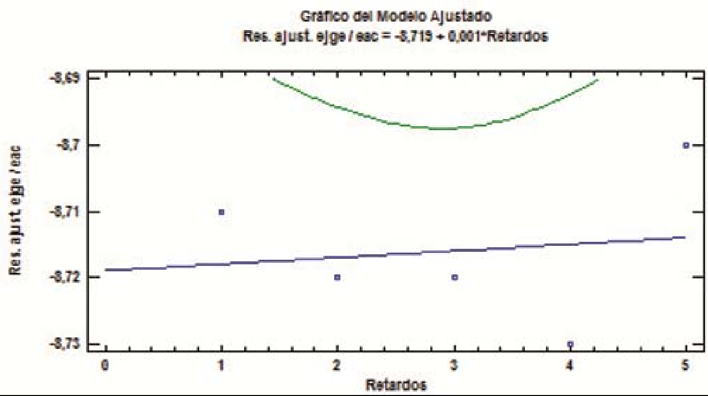
Target behavior	Regression equation	*p*	Trend
espe	Adjusted residual *eac* / *espe* = -17.442 + 0.906*Lags	**0.0000*** **	
ejge	Adjusted residual .*eac* / *ejge* = -8.72 + 0.0*Lags	**1**	
ejgr	Adjusted residual *eac* / *ejgr* = -3.614 + 0.012*Lags	**0.18**	
eor	Adjusted residual *eac* / *eor* = -45.38 + 2.792*Lags	**0.0000*** **	

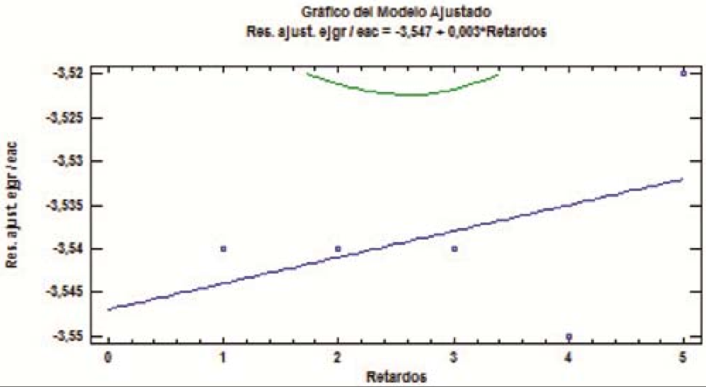
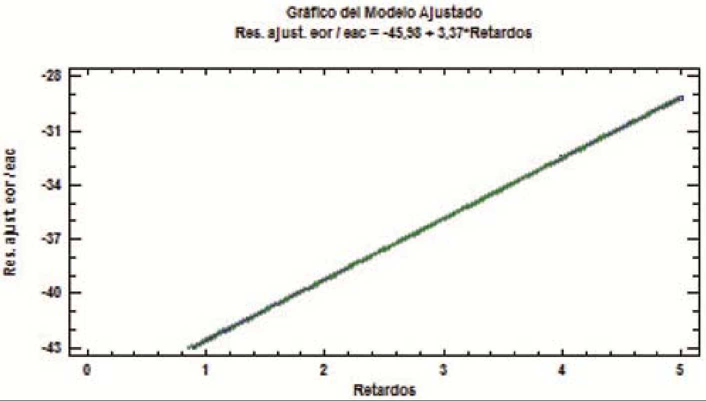
Target behavior	Regression equation	*p*	Trend
eirp	Adjusted residual *eac* / *eirp* = -4.692 + 0.176*Lags	**0.07**	
eiep	Adjusted residual *eac* / *eiep* = -9.299 + 0.903*Lags	**0.005****	

The regression equation linking *eac* (criterion behavior) to *eor* (conditional behavior) in Table 5—*eac* / *eor* = -45.38 + 2.792*Lags—provides information on the association between the behaviors that complements the results of the T-pattern and lag sequential analyses. The existence of a negative value at lag 0 (concurrence) again shows that these behaviors do not occur simultaneously, but rather in alternation, as seen previously in the T-pattern analysis.

Table 7. Regression equation results and adjusted residual graphs (lag sequential analysis), with the *eac* category as the conditional behavior.

Criterion behavior	Regression equation	*p*	Trend
eiep	Adjusted residual *eiep* / *eac* = -9.102 + 0.636*Lags	**0.009****	

<table>
<tr><th>Criterion behavior</th><th>Regression equation</th><th>p</th><th>Trend</th></tr>
<tr><td>eirp</td><td>Adjusted residual eirp / eac = -5.47 + 0.88*Lags</td><td>0.0000***</td><td>
</td></tr>
<tr><td>espr</td><td>Adjusted residual espr / eac = -14.93 + 0.46*Lags</td><td>0.0001***</td><td>
</td></tr>
<tr><td>espe</td><td>Adjusted residual espe / eac = -16.801 + 0.271*Lags</td><td>0.0000***</td><td>
</td></tr>
<tr><td>ejge</td><td>Adjusted residual ejge / eac = -8.719 + 0.001*Lags</td><td>0.82</td><td>
</td></tr>
</table>

Criterion behavior	Regression equation	*p*	Trend
ejgr	Adjusted residual *ejgr* / *eac* = -3.547 + 0.003*Lags	**0.46**	
eor	Adjusted residual *eor* / *eac* = -45.98 + 3.37*Lags	**0.0000*** **	

The regression equation linking *eor* (criterion behavior) and eac (conditional behavior) was *eor* / *eac* = -45.98 + 3.37*Lags. Again, the existence of a negative value at lag 0 shows that these two events cannot occur simultaneously, regardless of whether or not they occur in the same setting (*m1*).

The final analysis of the organization of class time, particularly with respect to the relationship between *eac* and the other categories, was performed using polar coordinate analysis.

Polar coordinate analysis

Polar coordinate analysis is a powerful data reduction technique that depicts complex relationships between a given category, known as a focal category, and other categories in the form of vectors. We applied the technique to show the network of relationships between *eac* (the focal behavior, which corresponds to the given behavior in lag sequential analysis) and the other categories in SOC-IS (conditional behaviors) to generate a map showing the various interactions between categories. The technique was proposed by Sackett (1980) based on previous work by Bakeman (1978) and was subsequently enriched by the incorporation of the concept of genuine retrospectivity (Anguera, 1997). Used in combination with SOC-IS, it has proven very useful in studies analyzing children's behavior in the classroom (Anguera, Espinosa, & Santoyo, 2002; Anguera, Santoyo, & Espinosa, 2003; Espinosa, Anguera, & Santoyo, 2004) and in other observational studies (Hernández-Mendo & Anguera, 1998; Anguera & Losada, 1999; Aragón, Lapresa, Arana, Anguera & Garzón, 2017; Castañer et al., 2016; Gorospe & Anguera, 2000; Herrero, 2000; López, Valero, Anguera & Díaz, 2016; Morillo, Reigal & Hernández-Mendo, 2015; Perea, Castellano, Alday & Hernández-Mendo, 2012). We believe that polar coordinate analysis would also be a valuable tool for analyzing the impact of self-regulation interventions in children with high rates of behavior transitions (Norris, 2016; Slattery, et al., 2016).

Following Cochran's proposal (1954), the prospective adjusted residuals (positive lags) and retrospective adjusted residuals (negative lags) generated in the lag sequential analysis were used, respectively, to compute prospective and retrospective Z_{sum} values, which in turn were used to calculate vector length and angle.

The resulting vectors are located in different quadrants, depending on their angle: 0-90º corresponds to quadrant I, 91-180º to quadrant II, 181-270º to quadrant III, and 271-360º to quadrant IV. Quadrants I and III are symmetric, while quadrants II and IV are asymmetric. Quadrants I and III correspond, respectively, to mutual activating and inhibitory interactions. Quadrant II corresponds to an inhibitory relationship between the criterion and the conditional behavior (or an activating relationship when the opposite direction is detected), while quadrant IV corresponds to an activating relationship between the criterion and the conditional behavior (or an inhibitory relationship for the opposite direction).

The use of polar coordinate analysis has been greatly facilitated by the inclusion of a dedicated feature in the software program, HOISAN. All the vector parameters were calculated and displayed as graphs using this program (version 1.6.3.2) (Hernández-Mendo, López-López, Castellano, Morales-Sánchez, & Pastrana, 2012).

The results of the polar coordinate analysis are shown in Table 8 and Figures 6 and 7.

Table 8. Polar coordinate analysis results, where the *eac* category was considered the focal behavior and the other categories were considered the conditional behaviors. The asterisk (*) indicates that the vector length (which reflects the strength of the relationship between the corresponding categories) was significant.

Focal Behavior	Categories	Quadrant	Prospective perspective	Retrospective perspective	Radius	Angle
eac	Episode_espr	II	-2.65	0.04	2.65 (*)	179.03
	Episode_espe	III	-1.15	-2.38	2.65 (*)	244.13
	Episode_esne	III	-1.17	-1.18	1.66	225.2
	Episode_esnr	III	-1.17	-0.09	1.17	184.36
	Episode_ejge	III	-2.83	-1.37	3.14 (*)	205.9
	Episode_ejgr	III	-1.65	-1.37	2.15 (*)	219.65
	Episode_eac	I	4.81	4.81	6.8 (*)	45
	Episode_eor	I	0.94	1.33	1.63	54.71
	Episode_eal	IV	0	0	0	0
	Episode_eja	III	-1.17	-1.81	2.16 (*)	237.2
	Episode_ejp	IV	0	0	0	0
	Iniation_eirp	II	-2.56	0.11	2.56 (*)	177.56
	Iniation_eiep	III	-2.49	-4.45	5.1 (*)	240.82
	Iniation_eien	III	-1.17	-1.18	1.66	225.2
	Iniation_eirn	III	-0.14	-0.78	0.79	259.96
	Area_m1	I	8.17	8.19	11.57 (*)	45.07
	Area_m2	III	-2.87	-4.35	5.21 (*)	236.56
	Area_m3	III	-1.17	-0.08	1.17	184.03
	Area_m4	II	-0.48	0.74	0.89	122.94
	Area_out	III	-6.93	-6.23	9.31 (*)	221.95

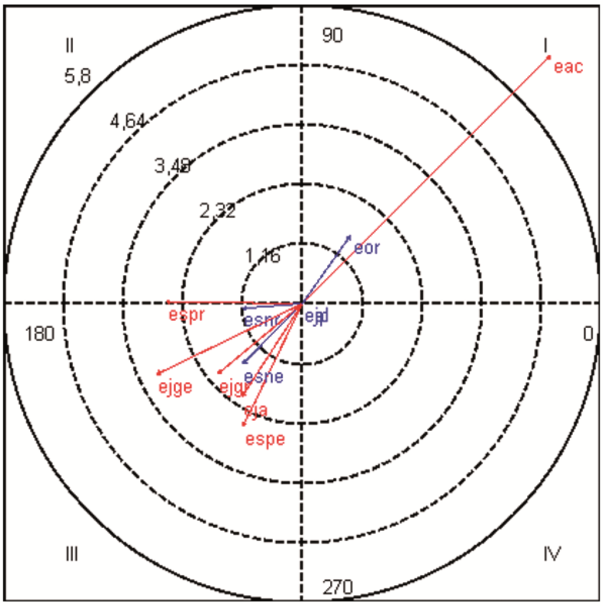


Figure 6. Polar coordinate vectors, where *eac* is the criterion behavior and *ejge* and *ejgr* (episode of social interaction categories) are the conditional behaviors. Vectors with a significant length or radius are shown in red, while those with a non-significant length or radius are shown in blue.

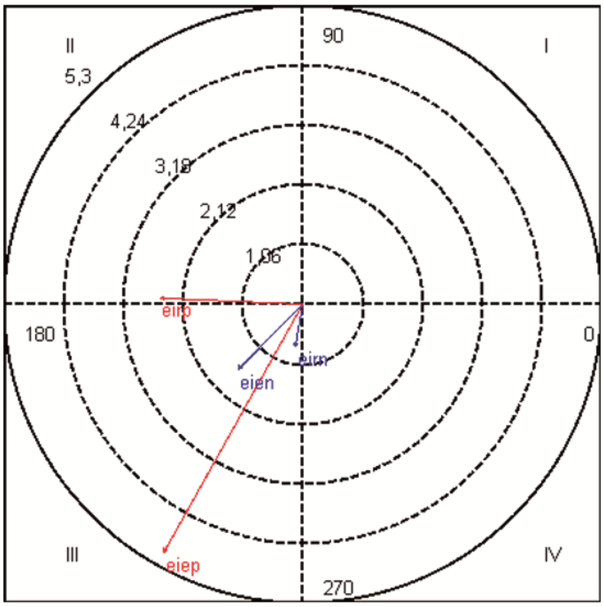


Figure 7. Polar coordinate vectors, where *eac* is the criterion behavior and *espr* and *espe (*initiation of social interaction categories) are the conditional behaviors. Vectors with a significant length or radius are shown in red, while those with a non-significant length or radius are shown in blue. Note that even though the relationship is not significant, there is a mutual inhibitory relationship between *eac* and *eirp* and *eie*, showing that these last two categories favor off-task behavior.

In quadrant I, the only category that had a mutual activating relationship with *eac* was *m1* (the corresponding vector had a length of 11.57 and an angle of 45.07°). Given the asymmetric relationship that characterizes quadrant IV, in which the focal behavior has an activating effect on all other categories in the quadrant, the only categories it could affect were *eal* and *ejp*, for which the corresponding vectors had null values.

While the results of quadrants II (inhibitory focal behavior) and III (mutually inhibitory focal and conditional behavior) are not directly pertinent to our analysis, they are consistent with the results of the other techniques. The fact that *eac* had a significant inhibitory effect on the social categories in quadrants II (*espr*, *eirp*) and III (*espe*, *esne*, *esnr*, *ejge*, *ejgr*, *eiep*, *eien*, and *eirn*) shows an "incompatibility" that permits a greater understanding of how time is organized in the classroom.

Discussion

The aim of this study was to show how complementary observational methodology techniques can be used to analyze the distribution of classroom behavior from the perspective of a single child. Our results therefore should be contemplated within the context of a case study, i.e., they are not intended to be generalized to the broader population of students. The majority of studies in this area have based their findings on information collected through questionnaires and other sources of indirect data. Studies of the distribution of time in classroom settings can offer highly relevant insights into what actually occurs in the classroom and how this impacts student motivation, academic activities, and other relevant experiences. The main strength of the current study is that we analyzed behavioral patterns related to academic tasks performed by primary school children from an individual and group perspective.

Our specific aim was to use four complementary techniques to study relationships between on-task behavior and other interaction categories to analyze how students spend their time in the classroom. We focused on on-task behavior (the *eac* category) to address some of the gaps in knowledge on how classroom time is organized.

Considering, a priori, that it is difficult to interpret relationships between the *eac* category and other interaction categories using any of the four techniques—T-pattern detection, lag sequential analysis, trend analysis, and polar coordinate analysis—in isolation, we decided to use a combination of the techniques and assess the convergence between results.

Table 9. Side-by-side comparison of T-Pattern detection, lag sequential analysis, trend analysis, and polar coordinate analysis results. The asterisk (*) indicates that the vector length (which reflects the strength of the relationship between the corresponding categories) was significant.

		T-Pattern	Polar coordinate analysis					Lag sequential anal.		Trend analysis	
				Prospective perspective	Retrospective perspective			eac as given	eac as given	eac as target	eac as given
Focal	Categories	Event-types	Quadr.			Radius	Angle				
eac	Episode_espr	-	II	-2.65	0.04	2.65 (*)	179.03	Inhibitory	Inhibitory	Upward & significant	Upward & significant
	Episode_espe	-	III	-1.15	-2.38	2.65 (*)	244.13	Inhibitory	Inhibitory	Upward & significant	Upward & significant
	Episode_esne	-	III	-1.17	-1.18	1.66	225.2				
	Episode_esnr	-	III	-1.17	-0.09	1.17	184.36				
	Episode_ejge	-	III	-2.83	-1.37	3.14 (*)	205.9	Inhibitory	Inhibitory	Upward & NS	Upward & NS
	Episode_ejgr	-	III	-1.65	-1.37	2.15 (*)	219.65	Inhibitory	Inhibitory	Upward & NS	Upward & NS
	Episode_eac	-	I	4.81	4.81	6.8 (*)	45				
	Episode_eor	-	I	0.94	1.33	1.63	54.711			Upward & significant	Upward & NS
	Episode_eal	-	IV	0	0	0	0				Upward & NS
	Episode_eja	-	III	-1.17	-1.81	2.16 (*)	237.2				
	Episode_ejp	-	IV	0	0	0	0				
	Initiation_eirp	-	II	-2.56	0.11	2.56 (*)	177.56	Inhibitory	Inhibitory	Upward & NS	Upward & NS
	Initiation_eiep	-	III	-2.49	-4.45	5.1 (*)	240.82	Inhibitory	Inhibitory	Upward & NS	Upward & significant
	Initiation_eien	-	III	-1.17	-1.18	1.66	225.2	NS	NS		
	Initiation_eirn	-	III	-0.14	-0.78	0.79	259.96	NS	NS		
	Area_m1	eac.m1	I	8.17	8.19	11.57 (*)	45.07				
	Area_m2	-	III	-2.87	-4.35	5.21 (*)	236.56				
	Area_m3	-	III	-1.17	-0.08	1.17	184.03	Not analyzed	Not analyzed	Not analyzed	Not analyzed
	Area_m4	-	II	-0.8	0.74	0.89	122.94				
	Area_out	-	III	-6.93	-6.23	9.31 (*)	221.95				

Table 9 shows a side-by-side comparison of the results and helps to detect interpretative synergies.

The first finding of note is that according to the results of the T-pattern, lag sequential, and polar coordinate analyses, on-task behavior (*eac*) was not significantly associated with any other episodes and the only consistent connection observed was with *m1*.

Of particular note also is the statistically significant mutually inhibitory relationship between *eac* and both *ejge* (episode of group play in target child,) and *ejgr* (episode of group play in target peers). When the *eac* category was analyzed as the criterion behavior, both *ejge* and *ejgr* generated vectors located in quadrant III, indicating that play has a disruptive effect on on-task behavior. The adjusted residuals for lags R1 to R5 also exhibited an upward, albeit insignificant trend, indicating that the longer the play episode, the less likely the student is to start an academic task.

The *espr* (positive social interaction [prosocial behavior) by target child) and *espe* (positive social interaction in target peers) categories are also particularly relevant. Both exhibited a significant inhibitory relationship with *eac*, indicating that social interaction interferes with academic activity. In the case of *espe*, the relationship was also reciprocal, as the corresponding vector was located in quadrant III, unlike that of *espr*, which was located in quadrant II. The adjusted residuals for the positive lags R1 to R5 exhibited an upward trend, reflecting, in a statistically significant manner, the consolidation of this inhibitory relationship. The relationships between on-task behavior and social interaction (*espr* and *espe*) have important implications for education and the organization of classroom activities. The inclusion of categories that permit the identification of the person who initiates a social episode allowed us to confirm the motivational importance of actions initiated by the target child or his peers favoring off-task behavior. These aspects are evident in both the polar coordinate and T-pattern analyses.

Finally, the relationship between the *eac* category and both the *eirp* (positive social interaction initiated by peer) and the *eiep* category (positive social interaction initiated by target child) is also interesting. We observed a statistically significant inhibitory relationship between the two categories and *eac* as both the criterion and conditional behavior, highlighting the fact that initiation of social interaction distracts children from academic tasks. The *eiep* vector was located in quadrant III, while the *eirp* vector was located in quadrant II. The inhibitory nature of these categories was further supported in the trend analysis, as they exhibited an upward trend, regardless of whether *eac* was analyzed as the criterion or conditional behavior. Furthermore, in the case of *eiep*, the upward trend was statistically significant when *eac* was defined as the conditional behavior.

We have presented an extension of previous work by our group in the field of academic behavior (Santoyo & Anguera, 1992) that supports previous findings from observational methodology studies conducted in similar school settings (Santoyo et al., 2000, 2006). In particular, our study adds to the body of scientific literature on the distribution of classroom behavior that has focused on the time spent by teachers in getting their students started on a task. Time lost in achieving this logically has an effect on the time spent by students on academic tasks. One general limitation of studies in this area to date is that they have based their analyses on indirect data rather than on actual time spent on classwork or factors that influence on-task behavior. Future studies should address motivational factors in situ to shed light not only on the allocation of time by teachers in the classroom (Martinic, 2015) but also on the distribution of activities that form part of on- and off-task behavior during teacher-student and student-student interactions in the classroom (Santoyo, in press).

To conclude, the combined use of four complementary observational methodology techniques to explore in greater depth the distribution of classroom activities in a primary school setting shows that the methods converged in terms of essential information but also provided differential insights that, considered as a whole, add an interesting depth to the analysis. We believe that more studies should aim to enrich their analyses and interpretation of data by using complementary techniques.

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