Journal of the International Neuropsychological Society (2000), **6**, 1–11.

Frequency and duration of inattentive behavior after traumatic brain injury: Effects of distraction, task, and practice

JOHN WHYTE,[1,2] KRISTINE SCHUSTER,[1] MARCIA POLANSKY,[3] JEFFREY ADAMS,[1,4]
AND H. BRANCH COSLETT[5]

[1]Moss Rehabilitation Research Institute, Philadelphia, PA
[2]Department of Physical Medicine and Rehabilitation, Temple University School of Medicine, Philadelphia, PA
[3]School of Public Health, Allegheny University of the Health Sciences, Philadelphia, PA
[4]Drexel University, Philadelphia, PA
[5]Department of Neurology, Temple University School of Medicine, Philadelphia, PA

(Received February 17, 1998; Revised December 2, 1998; Accepted December 21, 1998)

Abstract

Traumatic brain injury (TBI) is associated with impairments of attention, most typically measured through tests of information processing, or by subjective symptom endorsement by patients, families, and clinicians. We have previously shown increased rates of off-task behavior among patients with TBI *versus* controls as defined by videotaped records of independent work in distracting environments. In this research, we report on a more detailed method of coding such videotaped records which allows measurement of the precise number of off-task behaviors, their durations, and their relationship to distracting events. Using this method, we studied 20 patients with recent moderate-to-severe TBI and 20 demographically comparable controls as they performed independent work tasks while being subjected to controlled distracting events. This research confirms that patients are markedly less attentive than controls both in the presence of distractions and in their absence, that distractions have an influence on off-task behavior in both groups, and that the disruptive impact of distractors wanes relatively quickly for controls but not for patients. The duration of distraction produced by various classes of distracting events appeared similar for patients and controls, although the power to detect differences in behavioral duration between groups was limited. The pattern of inattentiveness among patients showed minimal relationship to measures of injury severity within this sample. (*JINS*, 2000, *6*, 1–11.)

Keywords: Brain injuries, Attention, Distraction

INTRODUCTION

Clinical literature consistently lists disorders of attention among the most prevalent cognitive sequelae of traumatic brain injury (TBI; Auerbach, 1986; Levin & Goldstein, 1989; van Zomeren, 1981; van Zomeren & Brouwer, 1994; van Zomeren et al., 1984; Whyte et al., 1998b). While clinicians and family members presumably base their reports of patients' attentional deficits on aspects of observable behavior within the context of everyday tasks, most research on attention in TBI has focused on controlled laboratory measures of information processing (e.g., Brouwer & van Wolffelaar, 1985; Cremona-Meteyard & Geffen, 1994; Ponsford & Kinsella, 1992; Schmitter-Edgecombe et al., 1992; Shum et al., 1994, van Zomeren, 1981; Whyte et al., 1995, 1997, 1998a). Thus, little is known about the overt attention-related behaviors that presumably form the basis of the judgments made by family members and clinicians. In order to be able to understand the relationship between underlying attentional processes measured in laboratory information processing tasks, and clinically observable inattentiveness, it is necessary to have measures for the latter that are comparably quantitative to the former.

We have been interested in how the purported attentional abnormalities common in TBI manifest themselves in naturalistic settings. In order to study this, we developed a set of standardized independent work tasks that participants perform in distracting environments. Within these tasks, we have

---

Reprint requests to: John Whyte, Moss Rehabilitation Research Institute, 1200 W. Tabor Road, Philadelphia, PA 19141. E-mail: whyte@vm.temple.edu

defined *off-task behavior* as episodes of looking up and away from the task materials and/or engaging in unsolicited conversation with the research assistant. Our prior research has shown that, indeed, individuals with TBI show significantly more off-task behavior than controls, both in the presence of external distractions, and when left undisturbed (Whyte et al., 1994, 1996). However, measures of "fidgeting" behavior, modeled after the restless behaviors seen in attention deficit hyperactivity disorder (ADHD), did not distinguish the two populations (Whyte et al., 1996).

In our prior research, we used a very crude method of coding off-task behavior. Videotaped records of behavior were divided into 15-s epochs. Each epoch was then defined as on-task (if *no* off-task behavior occurred within the interval) or off-task (if off-task behavior occurred *in any part of the interval*). This method of coding precluded any real quantitative analysis of the frequency, duration, or temporal arrangement of off-task behavior. Consequently, in the research we report here, we have revised our method of analysis to include a much more precise quantification of off-task behavior. Using this quantitative method, we have examined how such behavior is influenced by distracting events, different task contexts, and repeated sessions.

METHODS

Research Participants

A pool of brain-injured patients and comparable controls were tested as part of a larger program of attentional research. All brain-injured participants had a recent closed head injury sustained in a motor vehicle accident, fall, or interpersonal conflict, and were tested during their initial episode of inpatient rehabilitation at the Drucker Brain Injury Center at MossRehab. They were excluded if they had a prior history of traumatic brain injury resulting in loss of consciousness, prior central nervous system pathology, learning disability, attention deficit disorder, or major mental illness, or were taking medication (other than carbamazepine) known to affect cognitive function. Controls were recruited from hospital staff and community advertising. Exclusion criteria for controls were the same as for patients with the additional requirement that they had never suffered loss of consciousness from a traumatic brain injury. From the larger pool of participants, data records were randomly selected for 20 brain-injured individuals for the quantitative temporal coding described here. Records from 20 control participants were selected for comparison. The latter were chosen without regard to performance, but so as to ensure comparability to the selected patients in terms of sex, age, ethnicity, and years of education. Many of the participants described here also participated in other attentional assessment tasks in the same laboratory, both before and after these data were collected. Eleven patients and 14 controls whose data are analyzed here were also included in a previous publication on inattentive behavior that made use of a much less quantitative coding system (Whyte et al., 1996).

Brain-injured participants were tested as soon as they were cognitively and physically able to engage in the testing protocol and were free of excluded medications (time post-injury: *Mdn* = 66.5 days; range = 27–222 days). Standard measures of brain injury severity were not consistently available for patients, but Glasgow Coma Score (Teasdale & Jennett, 1974) recorded within the first 24 hr and estimated time until the patient first followed verbal commands were abstracted from referral records where possible. Unfortunately, in most instances it could not be determined whether the recorded GCS represented the initial score, or the best or worst score in the first 24 hr. All patients were out of posttraumatic amnesia (PTA) at the time of testing, but their durations of PTA were not consistently available. Disability Rating Scale Scores (Rappaport et al., 1982) at the time of testing were determined for all patients. Demographic characteristics of the selected patients and controls and brain injury severity indices for patients are summarized in Table 1. Patients and controls were compared on nominal variables (sex, ethnicity) using Fisher's Exact Test, and on continuous variables (age, years of education) using the Mann-Whitney *U* test. As shown in Table 1, the patient and control groups were well balanced demographically.

Table 1. Participant characteristics

Characteristic	Patients (*N* = 20)	Controls (*N* = 20)	*p*
Age (*Mdn*; range)	29; 17–55	28; 14–60	.63*
Sex (female/male)	5/15	7/13	.73**
Ethnicity (African American/Latino/White)	5/1/14	8/1/11	.51**
Years of education (*Mdn*; range)	12; 9–16	12.5; 8–16	.76*
GCS (*Mdn*; range; no. missing)	6; 3–14; 3	–	–
Estimated time until commands were followed (*Mdn* days; range; no. missing)	14; 0–61; 2	–	–
Disability Rating Scale score during testing (*Mdn*; range; no. missing)	5; 1–8; 0	–	–

*Mann-Whitney *U* test.
**Fisher's exact test (the comparison of proportions of Whites and non-Whites).

The research protocol was approved by the Institutional Review Board of MossRehab. Informed consent was obtained from each control participant and from patients or their surrogates. Patients and controls were paid for each testing session.

Procedure

All testing was conducted in a sound-damped laboratory adjacent to the hospital. In this experiment, participants were seated at a testing table, facing a video camera while they performed three independent work tasks during a single session. This set of three tasks was repeated in three separate sessions conducted at the same time of day. Each session was videotaped with a time code stamp that allowed later coding of behavioral events to be precisely sequenced and timed. Caffeinated beverages were prohibited beginning a few days prior to the study, and cigarette consumption among smokers was temporally controlled to avoid either nicotine withdrawal or stimulation during testing, as described previously (Whyte et al., 1996).

The three tasks were always performed in the same order. The participants were first asked to make a collage of their choosing on a large white piece of paper, using a glue stick and a bowl containing 320 squares and triangles of various colors of construction paper. Next they were presented with a bowl in the center of the table containing 192 pieces of each eight different items (e.g., pieces of pasta, nails, etc.), surrounded by eight smaller bowls, each of which had a single exemplar of a different item. They were asked to sort the items into individual bowls using their preferred hand. Finally, they were given a 500-piece jigsaw puzzle and asked to assemble as much of it as possible in the time allotted by referring to the photograph on the lid of the box. These tasks were selected to include a range of structured to unstructured activity, and to be able to be performed by participants of varying ability levels. Each task was 12–13 min long and was introduced with 1–2 min of verbal directions from a research assistant (R.A.), who also terminated each task after a total of 15 min (directions plus work time), for a total session length of about 45 min.

Participants could see the video camera and knew that the overall purpose of the larger testing protocol was to study attention, but were not informed about what aspects of their performance were being assessed in this particular experiment. Participants were informed that they needed to work on their own, but the need to be attentive was not specifically stressed. During each session the RA sat at a nearby table apparently doing his or her own work. The RA performed 12 naturalistic distracting behaviors, selected from four different distractor classes, during each session. The four classes of distractor were intended, potentially, to have different impacts on the participants: (A) distractors that involved the RA getting up from his/her chair and performing quiet tasks within the room (such as checking the thermostat), which were approximately 30 s in length; (B) distractors that involved brief, noisy behaviors performed at the RA's desk (such as dropping and retrieving a notebook), which were approximately 15 s in length; (C) colorful and noisy video games played by the RA within the participants' view, and lasting approximately 60 s; and (D) conversation distractors in which the RA dictated or telephoned someone else, and which lasted approximately 60 s. One member of each class of distractor occurred within each task, in pseudorandom order (instances of the same distractor class were never presented as the last distractor in one task and the first distractor in the next task). Their timing was controlled by an audiotape to which the RA listened through a small earphone. Participants were unaware that the distractors were an intentional part of the protocol. A different control tape, determined by a Latin-square design, was used for each session. Each tape specified similar but distinct distractors in different temporal locations. Distractors occupied slightly less than 20% of the working time (i.e., non-direction-giving time) in each session.

Videotape coding was performed by coders who were trained to criterion on separate training videotapes. Coding was done on a behavioral coding workstation (Observational Coding System Tools, 1995), without specific knowledge of the participants' clinical histories or performance on other attentional measures within the laboratory. Nevertheless, it was often possible to tell that a participant was a patient rather than a control. Coders viewed and listened to the videotapes to locate specific defined events. When a defined event was seen, the coders used slow frame analysis backward and forward to mark the beginning and end of the event with respect to the time code stamp, accurate to 33.3 ms (1 frame), thus allowing the onset time and duration of each event to be analyzed. Four types of events were coded: off-task behavior (eyes or head directed away from the task materials, or conversation with the RA); the presence of 1 of the 12 distractors; time-out periods (intervals of direction giving or RA intervention—these were excluded from data analysis); and extraneous motor (fidgeting) and extraneous vocal behavior (results not discussed here).[1]

Data Analysis

Interrater agreement was measured by Cohen's Kappa in terms of whether a relevant behavioral event occurred and what type of event it was. The temporal discrepancy between raters for agreed-upon events was examined with descriptive statistics. Factors influencing the frequency of off-task events were analyzed through hierarchical log-linear modeling, with *post-hoc* testing conducted via the Mann-Whitney U (for between-participants differences) or Wilcoxon Signed Ranks (for within-participant differences) Tests. Influences on the duration of off-task events similarly were analyzed with the Wilcoxon Signed Ranks Test (for within-participant comparisons) or the Mann-

---

[1] Operational coding procedures for these events are available upon request from the authors.

Whitney U Test (for between-participants comparisons). The impact of injury severity on inattentive behavior was examined with Spearman rank-order correlations.

RESULTS

Interrater Reliability

Two coders independently coded approximately 20% of the sessions for reliability purposes, but the data used for this analysis were those from the first coder to review the tape. Off-task and distraction events coded within 1 s and time-out events coded within 3 s by both raters were defined as the same event after reviewing preliminary histograms of the time discrepancies between raters. When two raters both identified the same event within the above time windows, they essentially never disagreed as to what type of event it was (i.e., there was no confusion among event categories). Rather, disagreements consisted almost exclusively of one coder failing to code an event seen by another coder, or one coder identifying several short events which another coder identified as a single longer event. When tapes were reviewed for these disagreements, errors were determined to be nearly always false negatives (i.e., one rater missed an event that was present).

Cohen's Kappas for each event type are shown in Table 2, considering both subject groups together (interrater reliability was not related to participant group). As can be noted, mean and median Kappas were quite high, but there were occasional very low agreement scores. Upon inspection of these, it was clear that low Kappa values occurred when the number of relevant events was very small and a disagreement occurred; Kappa is extremely sensitive to disagreement when the sample in one rating category is small (Cicchetti & Feinstein, 1990). Also of note is the perfect agreement regarding distractors. This is due to the fact that the coders had access to the same audiotape cues that instructed the RA to perform the distractor, since the RA performing the distracting behavior was generally not visible on the videotape.

In addition, we were concerned that the probability of missing an event might be related to event frequency, which could introduce bias (assuming a higher off-task event frequency among patients). To assess this, the number of events seen by *one or the other or both* coders was assumed to represent the "true" number of events (recognizing that even this slightly underestimates true events on occasions when both raters miss an event). The proportion of the events seen by each coder was plotted against the true number of events to assess the presence of systematic bias. Overall, it appeared that each coder was likely to miss approximately 7% of the total number of off-task events (where "total" is defined as the events seen by *either* coder). The proportion of missed events was graphed against the total number of events in each session. Visual inspection did not suggest a systematic relationship, and a linear regression confirmed the fact that there was no significant relationship for either patients or controls.

Table 2. Agreement regarding event occurrence*

	Cohen's Kappa		
Statistic	Off-task behavior	Distractor	Time-out
Mdn	.88	1.0	1.0
M	.84	1.0	.94
Range	0–1.0	1.0–1.0	.33–1.0

*Based on double coding of a sample of approximately 20% of sessions.

When coders agreed on the presence of an off-task event, their temporal agreement was compared. The median temporal discrepancy (absolute value) between the coders was 70 ms for the onset of off-task events, 100 ms for the end of off-task events, 230 ms for the onset of distractors, and 170 ms for the end of distractors.

Duration of Distractor Impact

We ultimately wished to examine the prevalence of off-task behavior under the influence of distracting stimuli, and during quiet times when no distractors were administered. This raised two questions: (1) Is the increase in off-task behavior induced by distractors constant throughout the distracting interval? and (2) Does the disruptive impact of distractors last beyond their termination? In order to define intervals of time which were clearly baseline (undistracted) intervals, a curve-fitting strategy was used. The probability of an off-task event beginning during each second of the distractor was calculated separately for patients and controls, collapsing over participants, sessions, tasks, and different instances of the same distractor class. For both groups, inspection of these data revealed a high probability of off-task behavior at distractor onset, a declining probability thereafter, and ultimately a constant low (baseline) probability of off-task behavior some time after distractor termination. In order to estimate the *behavioral* duration of the distractors, we deleted a 10-s section of the data that was ambiguous (i.e., the portion where the declining tail of the curve merged with the flat baseline). We then fit a logarithmic function to the left-hand portion of the data, and plotted a horizontal line through the mean of the right-hand portion of the data. The intersection of these two functions was operationally defined as the end of the behavioral duration of the distractor (see Figure 1). The logarithmic portion of the function accounted for only a modest portion of the variance, as shown in Table 3. This is because the dependent variable, proportion of observations which were off-task, occurred in only finite increments (only zero, 1, 2, etc., of the 20 participants observed in each task and session could be off task). Similarly, the increasing variability in the right hand portions of the graphs is only apparent. As the interval of observation is lengthened, more and more intervals are censored by the onset of another distractor (in a different

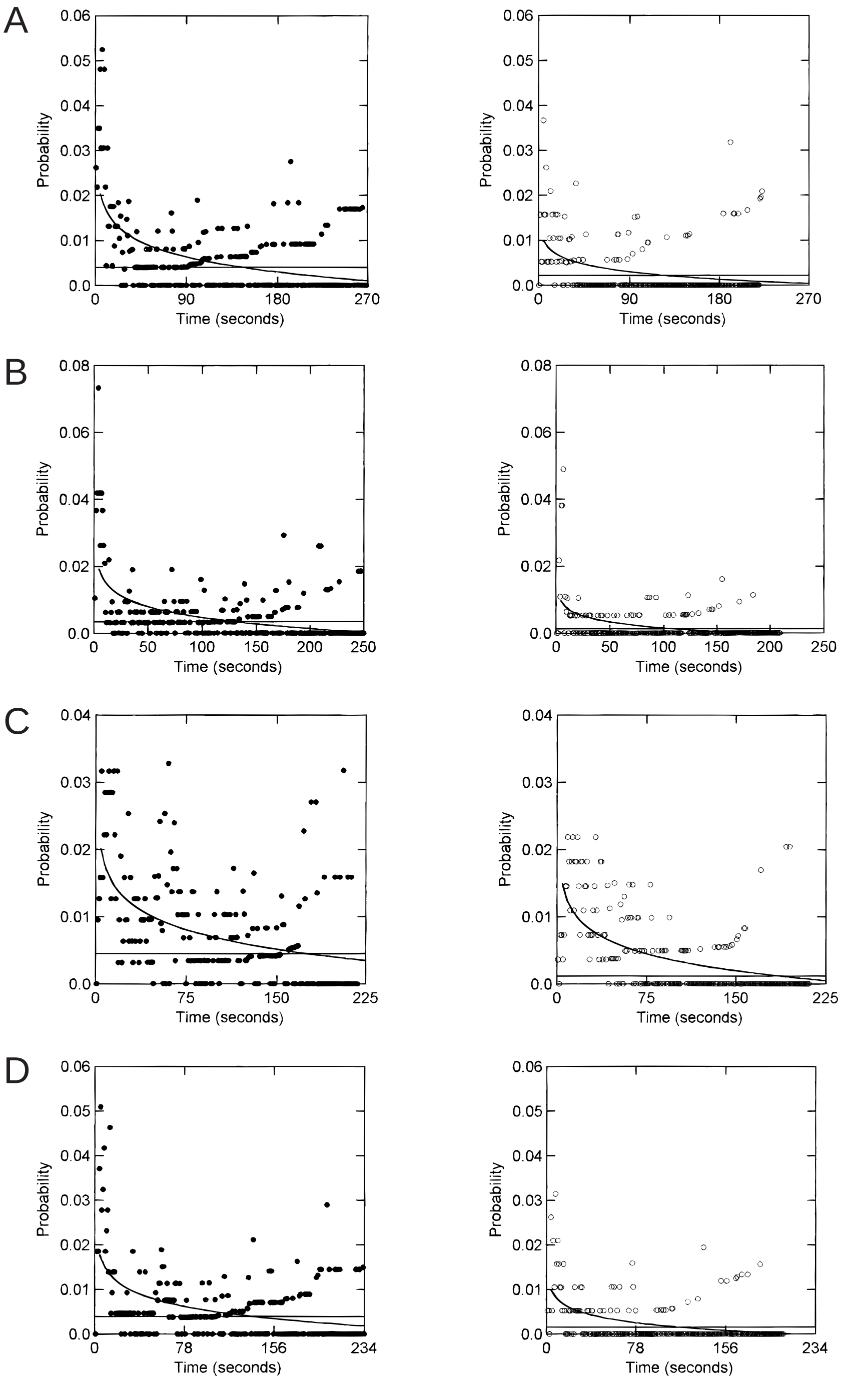

Fig. 1. Figures 1A–D demonstrate the probability of an off-task event beginning each second after the onset of a given type of distractor. Figure 1A corresponds to distractor class A (quiet motion), 1B to distractor class B (brief noise), 1C to distractor class C (video game), and 1D to distractor class D (conversation). In each panel, the left hand graph with filled circles represents patient data while the right-hand graph with open circles represents control data. Data for each participant group were collapsed over sessions, tasks, and different instances of the distractor class, to calculate the proportion of observations in which an off-task event began in each 1-s interval. The curved line represents a logarithmic curve fit to the left hand portion of the data. The horizontal line represents the mean proportion of off-task events occurring in undistracted baseline time. Note that, while the absolute levels of off-task behavior differ between patients and controls, the points of intersection between logarithmic and linear functions are strikingly comparable.

distractor class), leaving fewer intervals in the denominator, thus increasing the size of the increments in proportion caused by any individual off-task episode.

Although the logarithmic function captured a minority of the variance, a plot of the regression residuals for both groups and each distractor class revealed no systematic pattern and

Table 3. Duration of distractor impact

	Actual distractor duration	Point of intersection (behavioral duration)		r^2 for logarithmic function	
Distractor class	Time (s)	Patients Time (s)	Controls Time (s)	Patients r^2	Controls r^2
A	30	56	65	.44	.22
B	15	30	31	.43	.08
C	60	185	182	.23	.33
D	60	65	68	.26	.11

slopes of these residuals were all nonsignificant. This suggests that this method of defining behavioral duration, while somewhat imprecise, was unbiased. Using this method, behavioral durations of the various distractor classes were clearly different, while the durations for the two groups within the same distractor class were quite similar (see Table 3). The behavioral effect of all distractors lasted beyond their actual duration. The distractor class with the most prolonged impact was Class C (computer games). Although the games themselves lasted only 60 s, they had discernible effects for more than 3 min in both groups.

Influences on the Frequency of Off-Task Behavior

For the sake of uniformity, therefore, we defined undistracted time as those periods of time from which all distractors plus the subsequent 125 s had been deleted (i.e., we deleted the *longest* observed residual effects from all distractor classes). Preliminary analysis revealed that rates of off-task behavior during baseline intervals were unrelated to the specific type of distractor that preceded them; thus, all nondistracted time within a given task and session was viewed as a single baseline against which to compare distracted intervals.

Because distractors varied in length, we defined distracted time as the first 15 s of each distractor, which was the shortest distractor length, thus allowing us to compare the potency of different distractors during standardized initial 15-s observation intervals. Consequently, our comparison of behavior during distracted and nondistracted time was actually a comparison of the first 15 s of all distractor events (about 27% of all distracted time) with all portions of the session that were clearly at baseline (about 19% of all nondistracted time).

Hierarchical log-linear modeling of the influences on off-task behavior was conducted as follows. The number of off-task events that *began* during each 15 s distractor interval was counted. The number of off-task events that began during each undistracted interval was also counted, but then prorated into the number of events that would have occurred in a 15-s interval of undistracted time. (Although the first 15 s of distracted time were used for this analysis, *all* undistracted time in the same session and task were used for comparison. Thus, the number of off-task events occurring in the undistracted time had to be adjusted to a rate per 15-s interval). After examining simple tabulations of the number of off-task events, three levels of off-task behavior were defined: zero (*an event rate of 0/15 s of observation*); 1 (*greater than zero but less than 2 events/15 s*); 2 (*2 or greater events/15 s*). A log-linear model was constructed using the factors Group (patient *vs*. control); Session (first, second, or third); Task (collage, sorting, puzzle); and Distractor Type (Class A, B, C, D, or undistracted baseline from a given session and task). Backward elimination (beginning with a saturated model) was performed to fit the most parsimonious model using likelihood ratio chi-square tests to determine the inclusion or removal of specific effects.

Descriptive statistics relevant to the effects of the different independent variables were also calculated. First, the number of off-task events originating in each distractor or baseline nondistractor interval was counted and the length of the interval of observation (15 s for the distractor intervals and variable lengths for the nondistractor intervals) was identified. A rate of off-task behavior was then calculated (events/min), by adding up all of the events in the relevant intervals and dividing by all of the observation time in those same intervals. Off-task event rates are shown separately for the two groups, as they are affected by the three independent variables, demonstrating that patients' off-task behavior is consistently greater than controls' in all conditions (see Figure 2).

The most parsimonious log-linear model [$G^2(156) = 170.5$, $p = .202$] included significant effects of each factor of interest on the frequency of off-task behavior among study subjects. As expected, patients exhibited more off-task behavior ($M = 1.07$ events/min) than controls [.40 events/min; $G^2(6) = 113.6$, $p < .001$]. There was also a significant main effect of session [$G^2(8) = 23.73$, $p = .0025$], with reductions of off-task behavior over time, particularly between the first and second sessions (.83, .68, and .65 events/min respectively for Sessions 1–3). The influence of task was also highly significant [$G^2(4) = 36.82$, $p = <.0001$], with greatest off-task rates during the collage task (.86 events/min) and similar rates during the sorting (.70 events/min) and puzzle tasks (.68 events/min).

Finally, as expected, distractor type (including nondistracted time) significantly influenced the rate of off-task behavior [$G^2(8) = 158.68$, $p < .001$]. When average rates of off-task behavior for the four distractor classes were compared with the rate during undistracted time, the difference was highly significant in both subject groups (Wilcoxon signed ranks test, z-score approximations 3.59 and 3.88 for controls and patients respectively, $p < .001$ for each group). The impact of distraction, as measured by a difference between these two rates, was significantly different between groups. Patients' rate of off-task behavior increased by a median of 1.48 events/min with distraction, whereas controls' rate increased only by .44 events/min [$U(20,20) = 110.5$, $p = .015$]. However, this comparison is confounded

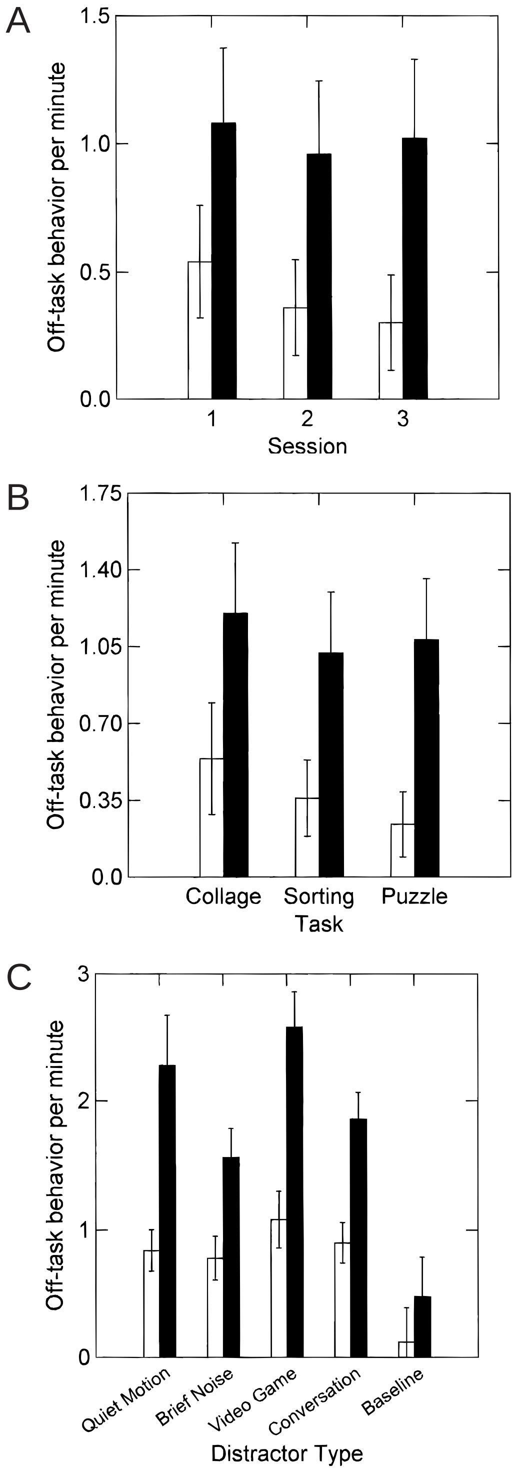

Fig. 2. The frequency of off-task behavior is displayed for patients (filled bars) and controls (open bars) across sessions (Figure 2A), tasks (Figure 2B), and type of distractor (Figure 2C). Note that in all of these graphs, off-task behavior among patients is more prevalent than among controls for the same independent variable.

by floor effects in that 8 controls and 3 patients had no off-task episodes in the absence of distraction across the three sessions. Therefore, we eliminated these participants and calculated difference scores for those remaining, reflecting their frequency of off-task behavior with distractors present minus their frequency with distractors absent. The median impact of distractors by this measure was 1.5 episodes/min for patients and .6 episodes for controls [$U(12,17) = 70$, $p = .16$]. The lowest rates of off-task behavior occurred during undistracted intervals (.29 events/min), while rates during distraction ranged from 1.20 to 1.85 events/min, depending on the nature of the distraction. The highest rates of off-task behavior were seen during the visually compelling and noisy computer game distractions (Class C).

In addition, there was a significant interaction between Group × Session [$G^2(4) = 9.89$, $p < .05$], with greater and more abrupt reduction in off-task behavior in controls than in patients. As seen from the main effect of session, and the interaction of Session × Group, controls appeared to become more attentive with each session, while patients did not. We examined this issue in greater detail to determine whether changes in off-task behavior occurred during the intervals containing distraction, the undistracted intervals, or both. This was done by comparing the rates of off-task behavior in Session 1 *versus* Session 3 separately for distracted and undistracted intervals, using the Wilcoxon signed ranks test. This revealed that patients showed little improvement either in the distracted ($M = 2.23$ events/min in Session 1 *versus* 2.06 events/min in Session 3) or undistracted conditions (.54 *vs*. .51 events/min). In contrast, controls showed about a 50% reduction in off-task behavior across sessions for the distracted intervals (1.29 *vs*. .65 events/min) and the undistracted intervals (.18 *versus* .07 events/min). The reduction of impact of distractors across sessions was significantly greater than the reduction of off-task behavior seen in their absence for controls (z-score approximation $= 2.92$, $p = .004$) but not for patients (z-score approximation $= .14$, $p = .89$). Despite the apparently greater decline in distractor impact across sessions among controls, a direct comparison of this rate of decline of distractor impact (rate of off-task behavior with distractors present: Session 1 − Session 3) in the two groups did not reach statistical significance [$U(20,19) = 244.5$, $p = .12$]. The discrepancy between the significant Group × Session interaction in the log-linear model and a nonsignificant trend in the same direction in the above analysis is most likely accounted for by the greater multivariate control allowed by the log-linear model.

Influences on the Duration of Off-Task Behavior

Because of the large number of intervals in which no off-task behavior occurred, a simple model of the duration of off-task behavior was redundant with the frequency analysis—the duration contrast done this way being essentially a contrast between zero and nonzero durations. Therefore, we chose to analyze influences on the duration of off-task behavior *when it occurred* (i.e., excluding all intervals with no off-task behavior). Unfortunately, this produced too many cells with missing data to allow us to conduct an analysis parallel to that used for frequency data. Instead, we simply compared mean durations of off-task behavior, using the Wilcoxon signed ranks test for within-participant comparisons and the Mann-Whitney *U* test for between-group comparisons, for each of the above factors, collapsing across all other factors. For example, when comparing the durations for patients *versus* controls, data were collapsed across session, task, and distractor type, precluding any examination of interactions among factors.

When collapsed over sessions, tasks, and distractor types, patients exhibited longer off-task behaviors than controls [$U(20,18)$, $p = .014$]. Two controls exhibited no off-task behavior in the sampled intervals. Of the remaining participants, the mean duration of each off-task event was 1.84 s for patients and 1.36 s for controls. The duration of off-task behaviors did not vary by session for either group (Wilcoxon signed ranks test: $.18 < p < .45$). Tasks had differing effects: patients and controls both exhibited the longest durations of off-task behavior during Task 1, but controls' duration was significantly shorter in Task 2 (Wilcoxon Signed Ranks Test (exact form): $p < .02$), whereas patients' duration was significantly shorter in Task 3 (z approximation = 1.97, $p < .05$; see Figure 3).

Off-task events were of approximately the same duration in each group whether they occurred during distraction or during undistracted time (Wilcoxon signed ranks test, z-score approximation = .21 for patients, .36 for controls; p values .83, .72 respectively). However, among patients, the specific distractors differed in their effects on the duration of off-task behavior. Distractor C (video games) produced longer off-task behaviors than any other distractor class except nondistraction ($.031 < p < .001$ for comparisons of distractor C with A, B, and D; $p = .227$ for comparison of distractor C with nondistraction). In contrast, the durations of off-task events among controls were not significantly influenced by the specific type of distractor used or by absence of distraction ($.37 < p < .08$; see Figure 4).

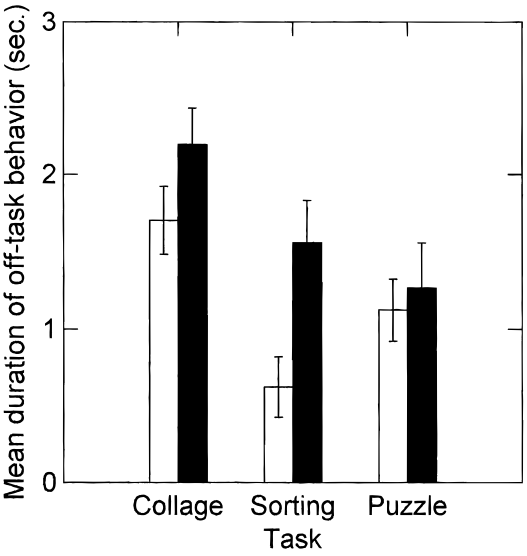

Fig. 3. In Figure 3, the duration of individual off-task episodes is displayed for patients (filled bars) and controls (open bars), across the three tasks, revealing that durations are longer for patients than controls overall, but that the two groups are differently affected by variations in the task.

Severity Correlates of Inattentive Behavior

Spearman rank-order correlations were used to examine the relationship between measures of off-task behavior (frequency and duration) and injury severity (GCS score, estimated time until commands were first followed, and current DRS score). Spearman correlations between measures of injury severity and off-task behavior were modest although the sample size for these calculations was somewhat small, due to unavailability of severity measures for some participants. Current disability scores (by DRS) were associated with duration of off-task events during both distracted and nondistracted intervals ($\rho = .51, .64$ respectively; ps = .02, .006). In contrast, there was no significant association between disability level and frequency of off-task behavior either with or without distraction ($\rho = .07, .24$ respectively; ps = .79, .31). None of the relationships with other severity measures approached significance.

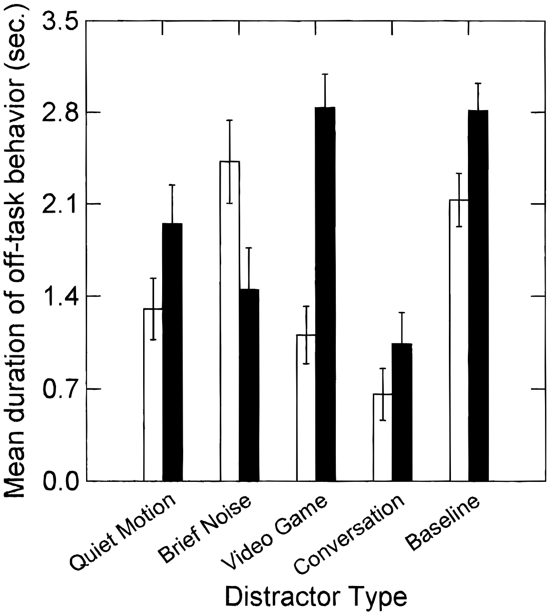

Fig. 4. The mean duration of individual off-task episodes among patients (filled bars) and controls (open bars) is shown for each of the distractor types, demonstrating that, for patients, off-task durations induced by the video game are longer than those associated with other distractors, and comparable in length to spontaneous off-task behavior. Although controls also appear to show distractor-related differences in duration of off-task behavior, none of these differences were significant.

DISCUSSION

In this research, we report a quantitative method of assessing inattentiveness, as manifested in clinically observable off-task behavior. This method allows measurement of the precise number of episodes of off-task behavior during periods of environmental distraction and undistracted time, as well as the duration of each such episode, with good interrater reliability. The results obtained with this method confirm our previous findings that patients exhibit significantly more frequent off-task behavior than controls, not only in the presence of specific environmental distractors, but also during undistracted time. This more sensitive method, however, has revealed some additional effects. Whereas task had no clear impact on off-task behavior in our previous research, this analysis revealed significant task effects in both groups, with the greatest degree of inattentiveness seen in the least structured task: the collage. Controls and patients, however, responded differently to repeated testing. Controls appeared to become more attentive with repeated sessions while this pattern was not seen among patients, at least within the three-session format that we used.

Clearly TBI results in an increase in off-task behavior overall, and even in the absence of distraction. Whether TBI also produces a specific susceptibility to environmental distraction remains ambiguous. The difference between rates of off-task behavior with distractors present and absent was larger for patients than for controls. However, since the rate of off-task behavior with distractors absent was zero for almost half the controls, the difference between distracted and undistracted rates may have been reduced by this floor effect in controls, leading to an exaggeratedly large measure of the impact of distractors in patients. When we eliminated participants who failed to show off-task behavior in the absence of distraction, there continued to be a larger impact of distractors on patients, but this difference was not significant.

The duration of episodes of off-task behavior was longer, on average, for patients than for controls. In principle, this could reflect a reduction in task goal maintenance among patients such that, once off-task, they have less drive to return promptly to the goal at hand. On the other hand, it could merely reflect the frequently replicated finding that patients with TBI exhibit slowed performance in a wide range of behaviors (van Zomeren, 1981), in this instance including the simple act of looking up from a task and then down again. The latter explanation appears more plausible, since the absolute difference between groups in duration of off-task behaviors was relatively small (i.e., patients did not remain off-task for prolonged intervals as they might if they had lost track of the task goals) and current disability level correlated with off-task duration but not frequency. The fact that off-task duration tended to be longer when the episodes were spontaneous than when they were provoked by distraction also supports the slowing explanation. When participants are off-task due to distraction, a persisting task goal may lead them to return promptly to task, whereas when they are spontaneously off-task, this may indicate a weaker task goal state. The fact that distractor Class C (video games) produced particularly long off-task episodes in patients may be related to its particularly compelling nature to patients—the noise and motion may have continued to summon their attention in ways that other ongoing distractors did not.

This analysis has also revealed some similarities between groups. First, we have documented the robust impact of our distraction methodology on both groups. Moreover, specific environmental distractors tend to produce increased rates of off-task behavior in both groups when they first appear, and the probability of off-task behavior begins to decline even during a single distracting event. Nevertheless, the disruptive influence of such environmental events continues for some time even after the events, themselves, have ended. The behavioral duration of the specific distractor classes appeared to be quite similar for patients and controls. However, this conclusion is based on a curve fitting method that, while unbiased, accounted for a minority of the variance. Thus, the curve fitting approach we used had limited power to detect small differences in behavioral duration between groups. The fact that the estimated behavioral durations of different distractor classes differed strikingly, while the durations for the two groups appeared similar, leads us to suspect that the similarities between groups in distractor effects may be real.

This research is subject to a number of potential limitations. First, defining the location of attention in relation to the direction of eye gaze is admittedly very crude. It is clearly possible for an individual to be attending to a task while their eyes are directed elsewhere, if they are engaged in relevant thought, or, conversely, to be physically oriented toward the task while thinking about an irrelevant topic. However, the pattern of results conforms to what one might predict on an attentional basis (e.g., worse performance for patients than controls, for distracted than undistracted time, etc.), lending support to the validity of the method. Furthermore, all observational approaches to assessing attention necessarily relate to overt behavior, and it is presumably behaviors such as those that were coded that contribute to clinicians' opinions about the distractibility of individual patients.

Secondly, although we have attempted to study inattentiveness in a naturalistic setting, it must be acknowledged that task performance in a testing room with an obviously visible video camera is hardly analogous to the environments where our study participants would normally be performing. This is a necessary compromise, however, because one can only define off-task behavior in relation to an intended target of attention, and in fully naturalistic settings, such targets are ambiguous or multiple, whereas in our task, the target was clearly specified (a table-top task).

Finally, the lack of relationship between performance and most measures of neurologic injury severity is somewhat surprising. This may reflect the imprecision in our measures of these neurologic variables as well as the varied intervals between injury and testing. GCS scores were abstracted retrospectively from acute care charts, and are not necessarily best or worst scores within a defined interval of time. Moreover, those with worse initial GCS scores were tested later, relative to their injury date, since they had to experience enough recovery to understand and perform the task. This variation in testing interval, therefore, may have diluted any initial severity effects. The fact that *current* severity level (as measured by the DRS score) did correlate with duration of off-task behaviors, supports this hypothesis. In addition, the patient-participants were recruited from an inpatient rehabilitation program that admits predominantly severely injured patients. It is likely that inclusion of a broader range of injury severity might have demonstrated a stronger relationship with performance.

In some ways it is the similarity between patients and controls that is the most surprising result of this research. Although patients had significantly greater rates of off-task behavior at baseline, many of the variables that influenced off-task behavior did so in comparable ways for patients and controls. That is, the influences of different tasks and distractor types were quite comparable across the two groups. Even the behavioral duration of the distractor classes was comparable. Indeed, the only interaction between group and another independent variable was with session, suggesting that inattentiveness improved more dramatically for controls than for patients with repeated task performance. If these similarities are confirmed by further research, they would suggest that, while environmental modifications may be helpful in promoting attentiveness in people in general, they have no special relevance for individuals with TBI. Rather, it will be important to learn more about the intrinsic factors that limit the ability of individuals with TBI to maintain an internally directed focus of attention. The possibility that some participants display a heightened sensitivity to environmental distractions cannot be ruled out, and may be revealed in larger studies and those that have the power to examine neurologically distinct subgroups.

We have developed a quantitative method of measuring off-task behavior during independent work tasks performed in a distracting environment. This method allows for more precise measurement of the frequency and duration of off-task behavior, and how it relates to specific environmental distractors. Using this method, we have characterized the time course of off-task behavior induced by environmental distractors. We have also shown that such off-task behaviors are more common among patients with TBI than among controls, more common in the presence of distractors than in their absence, and are affected by the nature of the task being performed. We have also found preliminary evidence that the disruptive impact of environmental distractors appears to wane more rapidly for controls with repeated presentation than for patients with TBI. In the future, we hope to examine the relationship between inattentiveness defined behaviorally, as reported here, and information processing measures of attention. In addition, we hope to use this method to examine treatments intended to improve attentional function following TBI.

ACKNOWLEDGMENTS

We would like to thank Chris Cavallucci, Adrian Slobin, Joanna Lhulier, and Angela Mullen for participant testing and coding of the videotapes, and Drs. Andrea Laborde, Gary Goldberg, Tessa Hart, Nathaniel Mayer, and Jeanne Pelensky for assistance in the recruitment and screening of patients. Special thanks are also due to Michael Montgomery for assistance with the log-linear modeling. Finally, we thank the subjects themselves and their families for participating in this research. This project was supported in part by Grant # R29 NS27715 (NINDS) to J.W., and by funds from Moss Rehabilitation Research Institute and Moss Rehabilitation Medicine, Inc.

REFERENCES

Auerbach, S.H. (1986). Neuronatomical correlates of attention and memory disturbances in traumatic brain injury: An application of neurobehavioral subtypes. *Journal of Head Trauma Rehabilitation*, *1*, 1–12.

Brouwer, W.H. & van Wolffelaar, P.C. (1985). Sustained attention and sustained effort after closed head injury: Detection and 0.10 Hz heart rate variability in a low event rate vigilance task. *Cortex*, *21*, 111–119.

Cicchetti, D.V. & Feinstein, A.R. (1990). High agreement but low Kappa: II. Resolving the paradoxes. *Journal of Clinical and Experimental Psychology*, *43*, 551–558.

Cremona-Meteyard, S.L. & Geffen, G.M. (1994). Event-related potential indices of visual attention following moderate to severe closed head injury. *Brain Injury*, *8*, 541–558.

Levin, H.S. & Goldstein, F.C. (1989). Neurobehavioral aspects of traumatic brain injury. In P. Bach-y-Rita (Ed.), *Comprehensive neurologic rehabilitation: Volume 2. Traumatic brain injury* (pp. 53–72). New York: Demos.

Observational Coding System Tools, Version 2.5b. (1995). Research Triangle Park, NC: Triangle Research Collaborative, Inc.

Ponsford, J. & Kinsella, G. (1992). Attention deficits following closed-head injury. *Journal of Clinical and Experimental Neuropsychology*, *14*, 822–838.

Rappaport, M., Hall, K.M., Hopkins, K., Belleza, T., & Cope, D.N. (1982). Disability rating scale for severe head trauma: Coma to community. *Archives of Physical Medicine and Rehabilitation*, *63*, 118–123.

Schmitter-Edgecombe, M.E., Marks, W., Fahy, J.F., & Long, C.J. (1992). Effects of severe closed-head injury on three stages of information processing. *Journal of Clinical and Experimental Neuropsychology*, *14*, 717–737.

Shum, D.H.K., McFarland, K., & Bain, J.D. (1994). Effects of closed-head injury on attentional processes: Generality of Sternberg's additive factor method. *Journal of Clinical and Experimental Neuropsychology*, *16*, 547–555.

Teasdale, G. & Jennett, B. (1974). Assessment of coma and impaired consciousness. *Lancet*, *2(7871)*, 81–84.

van Zomeren, A.H. (1981). *Reaction time and attention after closed head injury*. Groningen, The Netherlands: Krips Repro Meppel.

van Zomeren, A.H. & Brouwer, W. H. (1994). *Clinical neuropsychology of attention*. New York: Oxford University Press.

van Zomeren, A.H., Brouwer, W.H., & Deelman, B.G. (1984). Attention deficits: The riddles of selectivity, speed, and alertness. In N. Brooks (Ed.), *Closed head injury: Psychological, social, and family consequences* (pp. 74–107). New York: Oxford University Press.

Whyte, J., Fleming, M., Polansky, M., Cavallucci, C., & Coslett, H.B. (1998a). The effects of visual distraction following traumatic brain injury. *Journal of the International Neuropsychological Society*, *4*, 127–136.

Whyte, J., Fleming, M., Polansky, M., Cavallucci, C., & Coslett, H.B. (1997). Phasic arousal in response to auditory warnings after traumatic brain injury. *Neuropsychologia*, *35*, 313–324.

Whyte, J., Hart, T., Laborde, A., & Rosenthal, M. (1998b). Rehabilitation of the patient with traumatic brain injury. In J.A. Delisa (Ed.), *Rehabilitation medicine: Principles and practice* (*3rd ed.*, pp. 1191–1239). Philadelphia: Lippincott.

Whyte, J., Polansky, M., Cavallucci, C., Fleming, M., Lhulier, J., & Coslett, H.B. (1996). Inattentive behavior after traumatic brain injury. *Journal of the International Neuropsychological Society*, *2*, 274–281.

Whyte, J., Polansky, M., Fleming, M., Coslett, H.B., & Cavallucci, C. (1995). Sustained arousal and attention after traumatic brain injury. *Neuropsychologia*, *33*, 797–813.

Whyte, J., Rose, T., Glenn, M.B., Gutowski, W., Wroblewski, B., & Reger, J. (1994). Quantification of attention related behaviors in individuals with traumatic brain injury. *American Journal of Physical Medicine and Rehabilitation*, *73*, 2–9.