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Kraepelin and Bleuler Had It Right: People With Schizophrenia Have Deficits Sustaining Attention Over Time

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Abstract

An inability to sustain attention was noted in the original clinical descriptions of schizophrenia, but the vast majority of experimental studies have failed to report a performance decrement over time, calling this observation into question. To test for such deficits when task conditions conform to basic science taxonomy for the validity of sustained attention tasks, a dynamic stimulus array was presented in which targets, differing subtly from standard stimuli, were presented infrequently and unpredictably. Both people with schizophrenia (PSZ, N=40) and healthy control subjects (HCS, N=29) displayed a reduction in hit rate and an increase in reaction time from the first to the second 5-minute period. Thereafter, the hit rate of HCS recovered and remained stable, while that of PSZ continued to decline. When performance at task onset was equated between groups, the decrement over time in PSZ remained of the same robust magnitude. Thus, when the nature of the task challenges sustaining attention over time, PSZ display a clear deficit in this ability.

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Introduction

The idea that people with schizophrenia (PSZ) suffer from an inability to maintain attention to the task at hand is a concept with a long tradition in theories of cognitive dysfunction in schizophrenia (Nuechterlein & Dawson, 1984). Kraepelin (1919) noted that PSZ commonly "lose both inclination and ability on their own initiative to keep their attention fixed for any length of time", and Bleuler (1911, translated by Zinkin 1950) stated "The general tendency to fatigue in some cases also causes the rapid dwindling of attention (p. 69)." Thus, deficits in sustained attention[1] have been considered to be characteristic of schizophrenia since the first descriptions and definitions of the disorder. Similarly, a pioneer of experimental psychopathology, Shakow (1962), described the inability to maintain a major task set, i.e. to keep up a state of readiness to respond to a coming stimulus, as central to schizophrenia.

An inability to maintain attention to task goals could undermine performance on nearly any task, providing a compelling causal explanation of many other impairments observed in PSZ. Consistent with this notion, Green (1996) concluded that sustained attention is a core cognitive deficit of schizophrenia related to problem solving and skill acquisition.

While the performance of any task requires the maintenance of attention towards it, the degree to which this ability is challenged depends on task characteristics. A large body of basic research indicates that sustained attention is particularly challenged when the information processing demands to be maintained are resource consuming, i.e. when the processing load is high, or when target events occur infrequently, unpredictably and are of low salience (Parasuraman, Warm, & Dember 1987).

Experimental tests of the hypothesized sustained attention deficit in PSZ have largely used Continuous Performance Tasks (CPTs), in which items are presented at a constant rate, typically one per second, and interspersed target items require a response. Because they require a continuous task focus rather than short bursts of attentional effort, CPTs have face validity as a sustained attention paradigm. PSZ and their relatives display consistently lower target detection and more commission errors in CPTs than control subjects (Birkett et al., 2007; Buchanan, Strauss, Breier, Kirkpatrick, & Carpenter, Jr., 1997; Chen et al., 1998; Cornblatt, Lenzenweger, & Erlenmeyer-Kimling, 1989; Egan et al., 2000; Ito, Kanno, Mori, & Niwa, 1997; Jones, Cardno, Sanders, Owen, & Williams, 2001; Liu et al., 2006; Nuechterlein, 1983; Obiols et al., 1992; Orzack & Kornetsky, 1966; Pandurangi, Sax, Pelonero, & Goldberg, 1994; Pigache, 1996; Rutschmann, Cornblatt, & Erlenmeyer-Kimling, 1977; Seidman et al., 1998; Tsuang et al., 2006; Wang et al., 2007; Wohlberg & Kornetsky, 1973). A few other tasks with face validity for sustained attention also showed impairment in PSZ (Chan et al., 2009; O'Grada et al., 2009). In most cases, such impairment has been equated with a sustained attention deficit, disregarding the potential contribution of other functions that mediate accurate target detection, such as the adequacy of perceptual processes, processing speed, working memory, and response preparation. Thus, although reliable impairments have been observed in several versions of the CPT, it is not clear that these impairments reflect a deficit in the ability to sustain attention over time.

Unambiguous evidence of a sustained attention deficit in PSZ compared to healthy control subjects (HCS) would be a demonstration that PSZ exhibit a sharper decrement in target detection over time. This would capture the essence of the construct by showing that the maintenance of attention over time, specifically, poses problems, rather than suboptimal operation of other processes at any given moment. None of the above-cited studies identified

[1] "Sustained attention" is often used interchangeably with "vigilance", although vigilance may refer to the implied underlying state (alertness) that enables or impedes the maintenance of attention over time.

such a pattern, although only 4 out of the 20 studies reported testing for it, and the short task durations of generally less than 10 minutes may have precluded performance decrements over time. There are a few reports of this with perceptually challenging visual CPTs, around 10 minutes in length (Mass, Wolf, Wagner, & Haasen, 2000; Nestor, Faux, McCarley, Shenton, & Sands, 1990; Park, Kim, Kim, Kim, & Lee, 2011) and with a 5-minute auditory CPT (Pigache, 1999). A trend effect was also seen by Nuechterlein (1983). Overall, however, these reports are vastly outnumbered by studies using the same or very similar CPT versions that did not report a larger performance decrement over time in PSZ, although it is unclear how many of these studies actually tested for it. The overwhelming lack of evidence of such a finding in PSZ led Nuechterlein, Dawson, & Green (1994) to suggest that "although the vulnerability-linked deficit in information processing is revealed in a task that demands sustained attention, the critical deficit might not be in sustained attention per se." Similarly, on the basis of the persistent absence of a decline in CPT performance over time, Cornblatt & Keilp (1994) concluded that a dysfunction in sustained attention is not the critical deficit in PSZ. Nonetheless, deficits of PSZ on the CPT continue to be widely interpreted as sustained attention deficits.

Given the conflict between clinical intuition and experimental evidence, it is worth considering whether PSZ indeed have deficits in sustained attention that are simply not detected by the CPT and related tasks. While the present study does not seek to defend or undermine the validity of the CPT as a measure of sustained attention, it does seek to demonstrate the existence of a robust sustained attention deficit in PSZ, which has thus been called into question. To accomplish this, we designed a signal detection task that rigorously followed the criteria for the construct validity of vigilance tasks defined by Parasuraman et al. (1987) by combining a high processing load with low signal discriminability, probability and predictability.

Methods

Participants

Forty individuals meeting Diagnostic and Statistical Manual of Mental Disorders-IV (American Psychiatric Association, 1994) criteria for schizophrenia (N=16 paranoid, 13 undifferentiated, 3 residual, 2 disorganized, 1 catatonic) or schizoaffective disorder (N=5), and 29 HCS participated in this study. Diagnosis was established using a best estimate approach in which information from a Structured Clinical Interview for DSM-IV (SCID) was combined with a review of medical records at a consensus diagnosis meeting. Demographic information is summarized in Table 1. Groups did not differ in age [$t(67)=0.13$, $P>0.8$], parental education [$t(65)=0.26$, $P>0.7$], sex [Chi-square $P>0.9$] or ethnicity [Chi-square $P>0.4$]. However, PSZ had fewer years of education than HCS [$t(67)=4.06$, $P<0.001$], an expected finding given that the illness generally starts in early adulthood.

The PSZ were clinically stable outpatients (see Table 1 for a description of clinical ratings). All PSZ were receiving antipsychotic medication at time of testing; 5 were treated with first-generation antipsychotics, 33 with second-generation antipsychotics, and 2 with both. 23 PSZ additionally received mood stabilizing medication, 13 anxiolytic and 6 antiparkinsonian medication. Additionally, 1 patient received modafinil for sleep apnea, and 1 bromocriptine. Medication had not changed in the preceding four weeks. HCS were recruited from the community via random digit dialing and word of mouth and had no current Axis 1 or 2 diagnoses as established by a SCID, had no self-reported family history of psychosis, and were not taking any psychotropic medication. All participants provided written informed consent after procedures had been fully explained. Before volunteers with schizophrenia signed the consent form, the investigator, in the presence of a third-party witness, formally

evaluated basic understanding of study demands, risks, and what to do if experiencing distress or to end participation.

Neuropsychological testing

Participants completed the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999), the Wide Range Achievement Test Reading (Wilkinson & Robertson, 2006), the Wechsler Test of Adult Reading (Wechsler, 2001), and the MATRICS battery (Nuechterlein & Green, 2006). Neuropsychological testing was usually performed on a separate day to avoid fatigue. PSZ scored lower than HCS on the WASI ($P<0.001$, independent-samples t-test), WRAT ($P<0.005$), WTAR ($P<0.05$) and MATRICS battery ($P<0.001$; Table 1), and exhibited significant impairment in all MATRICS domains.

The “Raindrops” task

The task was presented in a dimly illuminated room on a 17” CRT monitor with a 60 Hz refresh rate. The circular task stimuli were analogous to raindrops appearing and fading on a windshield, with multiple drops visible at any moment in time, creating continuous intense processing demands. The stimuli were presented against a grey background (luminance approximately 28.4 cd/m^2) and were of a darker grey (11.5 cd/m^2) and black (3.8 cd/m^2). Eleven stimuli were visible on the screen at any one time (Figure 1A and B). The target locations were randomly chosen from among 48 possible locations, not visible to the subject, distributed evenly in 6 rows and 8 columns across the central 50% of the screen. The “drops” were dynamic; they started small and grey, grew bigger and blacker, and then shrank and disappeared. In total, each stimulus was visible for 1100 ms, during which it passed through 11 growth and shrinkage phases of 100 ms each (Figure 1C). Target stimuli differed from standard stimuli in that their color remained grey, whereas standard stimuli changed from grey to black. Standard stimuli started as a grey circle with a diameter of 0.33° of visual angle (stage 1), which turned black (stage 2). Next, a grey ring appeared around the black circle (stage 3) resulting in a total diameter of 0.66°. The grey ring then also turned black (stage 4). Again, a grey ring appeared around the now larger black circle, resulting in a total diameter of 0.99° (stage 5), and this ring also turned black (stage 6). Next, the stimulus regressed back through stages 5 to 1 and disappeared. Each of the 11 visible drops was in a different growth phase at any one time. As soon as one drop had completed all phases and disappeared, a new drop started to “grow” at a different location. Target stimuli differed from the standard stimuli in that grey never turned black (Figure 1C). Thus, standard and target stimuli were identical in stage 1, but started to differ at the onset of stage 2 (henceforward referred to as target onset), and the difference became gradually easier to discern until stage 6. The task consisted of pressing a response button when a target stimulus was detected. In total, 180 target stimuli were presented randomly throughout a continuous 30-minute test period. The only constraint on target timing was that at least 1100 ms elapsed between the disappearance of one target and the onset of the next. The number of targets presented per 5-minute period ranged from 18 to 39.

The task was practiced by first showing participants a dynamic image of both a non-target and a target stimulus, and repeating these presentations if desired. We aimed for each participant to have a solid representation of both types of stimuli. Participants were instructed to press a response button as quickly as possible each time they saw a target item. Participant then completed a 1-min practice run during which the onset of each target item coincided with a 100-ms white circle that highlighted the target location during phase 1 of the drop’s growth portion. Participants then completed another 1-min practice run during which the white ring highlighted each target for 100 ms during the last phase of its shrinkage portion with the purpose of reinforcing participants’ judgment of having seen a target, or to

draw participants' attention to missed targets. Participants then practiced the final version of the task, without any target highlighting, for 5 min.

Because of the large number of concomitant non-targets with a new stimulus onset every 100 ms, the Raindrops task does not provide a clear measure of the number of correct rejections and thus does not permit the determination of a discrimination index. Note, however, that %Hits and FAs were not positively correlated (see Results), ruling out the possibility that response bias significantly influenced these performance measures.

Data analysis

To determine whether a given response was a hit (detection of a target) or false alarm (misclassification of a non-target as a target), we used an iterative procedure to determine individual target response windows based on each participant's RT distribution. For each individual participant, we first plotted the RT for each first response following a target onset. Based on visual inspection, we determined that for all participants, responses bearing a systematic temporal relationship with targets occurred 200 to 2000 ms following target onset. To narrow down each participant's response window based on his or her individual RTs, we determined each participant's mean and standard deviation (stdev) of RTs within the 200 to 2000 ms window. Only the first response following a target was included within this window. Each participant's response window A was then defined as from 200 ms to (mean + 3 stdev) ms following a given target onset. We then determined the mean and stdev of all first-response RTs within response window A and defined each participant's final response window B as from 200 ms to (mean + 3 stdev) ms following a given target onset. The average RT across all participants based on response window B was only marginally faster (by 6 ms) than the average RT based on response window A, indicating that even response window A had been influenced by few individual outliers. For all analyses, the first response occurring within response window B of a target onset was classified as a target response. Any subsequent responses within this window (which were very rare) were ambiguous and therefore ignored (i.e. they were not treated as false alarms).

To examine changes in performance over the 30-minute task, the following performance indices were calculated for each 5-minute time period:

%Hits: The percentage of targets detected out of all targets presented. Because this measure is not normally distributed, the values were arcsine transformed for statistical analyses. Raw values are presented in the figures.

Reaction time (RT): The mean hit RT relative to the first moment at which a target could potentially be differentiated from a non-target (stage 2).

False Alarms (FAs): The number of responses that were made in the absence of a target, i.e. outside a target response window.

Each performance index was analyzed using a mixed-model two-factor ANOVA with Group (PSZ, HCS) as a between-subject factor and Time (period 1 through 6) as a within-subject factor, followed by one-factor ANOVA and Bonferroni-adjusted t-tests where indicated.

Results

%Hits

Figure 2A shows that for PSZ, the percentage of targets detected declined progressively over the course of the 30-minute session. HCS displayed a temporary decline from the first to the second 5-minute period, but target detection recovered thereafter and remained relatively constant. The group difference in performance over time was confirmed by an interaction

between Group and Time [F(5,335)=2.56, P<0.03]. Follow-up one-factor ANOVA confirmed a significant effect of Time in PSZ [F(5,195)=6.85, P<0.001] but not in HCS [F(5,140)<1]. The two-factor ANOVA also revealed a significant main effect of Group [F(1,67)=15.1, P<0.001], reflecting overall lower %Hits in PSZ. This group difference emerged early on in the time course of the task [period 1: t(67)=1.79, P=0.08, period 2: t(67)=2.41, P=0.02].

Two-factor ANOVA restricted to the first two 5-minute periods confirmed that both groups displayed a drop in %Hits from the first to the second period [main effect of Time: F(1,67)=6.84, P<0.02], although the effects were not significant in Bonferroni-corrected t-tests in the individual groups (Figure 2A). This initial decrement did not differ between groups [interaction of Group with Time: F(1,67)<1].

False Alarms

FAs averaged 7.6 ± 6.3 (stdev) in HCS and 26.3 ± 56.4 in PSZ across the entire session. The main effect of Group in two-factor ANOVA approached significance [F(1,67)=3.15, P=0.08]. Neither the main effect of Time, nor the Group × Time interaction was significant [F(5,335)<1 in each case]. The large number of FAs in PSZ was caused by four outlier subjects, each of whom made over 75 FAs during the task. Excluding these four participants reduced the average total number of FAs in PSZ to 10.4 ± 10.6, and the main effect of Group became P>0.2. Importantly, excluding these PSZ did not change the results for the other two performance measures (the Group × Time interaction on %Hits was now P<0.02).

The total number of FAs did not correlate significantly with the average %Hits in the total sample of PSZ (R=−0.26, P=0.1) or in HCS (R=−0.04, P>0.8). Note that the trend association seen in PSZ was negative, i.e. PSZ who made more FAs tended to detect fewer targets. This suggests that PSZ with a larger number of FAs had more problems discriminating target from non-target stimuli, but did not have a more general liberal response criterion (which would have resulted in a positive correlation). In other words, the tendency to make FAs did not artificially inflate %Hits. Furthermore, given that FAs did not vary with time on task, we can exclude that the decrement in %Hits over time was due to response criterion changes over time.

Reaction Time

RT displayed a slowing from the first to the second 5-minute period in both groups, similar to the initial decrement in %Hits. After the second period, RT in PSZ appeared to keep rising, while it recovered and leveled off in HCS (Figure 2B). However, only the main effects of Group [F(1,67)=4223, P<0.001] and Time [F(5,335)=2.94, P<0.02] were significant, not their interaction [F(5,335)<1]. Two-factor ANOVA restricted to the first two 5-minute periods confirmed that both groups initially displayed a RT slowing over time [main effect of Time: F(1,67)=9.31, P<0.004] that did not differ between groups [interaction of Group with Time: F(1,67)<1].

Controlling for overall performance

Performance was impaired overall in PSZ relative to HCS, even early on in task. If our task demanded cognitive processes other than sustained attention that are impaired in PSZ, then the added effort needed to compensate for the impairment in these processes could increase the challenge to uphold performance over time. We tested for the possibility that the performance decrement in PSZ was a secondary consequence of an overall greater difficulty performing the task by excluding the 13 lowest-performing PSZ based on their average %Hits across the entire session. The remaining PSZ did not differ from the HCS in age [t(54)=0.63, P>0.5], parental education [t(52)=0.38, P>0.7], sex [Chi-square P>0.6] or

ethnicity [Chi-square P>0.2]. The exclusion of low-performing PSZ resulted in identical target detection between this subgroup of PSZ (n=27) and the entire group of HCS (n=29) in the first two time periods (Figure 3). The high-performing PSZ displayed the same performance decrement over the remaining four time periods as the entire sample of PSZ. Two-factor ANOVA again confirmed a significant Group × Time period interaction [F(5,270)=2.49, P=0.03], but the main effect of Group was no longer significant [F(1,54)=2.20, P=0.14]. Thus, the difficulty of PSZ in sustaining attention over time was not caused by the overall greater challenge that performing the task posed to them.[2]

Association with other variables

To provide a single performance decrement index that could be correlated with other measures, each participant's time-on-task effect was quantified by subtracting the average %Hits in the last 10 minutes of the task from that in the first 10 minutes. We calculated Pearson correlations between this index and the seven MATRICS subscales and the WASI separately in HCS and PSZ, and with the four psychiatric rating scales in PSZ. Only one trend effect was observed, and this was for the correlation with the MATRICS Attention/Vigilance subscale in PSZ (R=−0.27, P=0.10). When analyzing this effect with a group split, PSZ who displayed a performance decrement as indexed by a positive decrement index (i.e. %Hits in the last 10 minutes of the task was numerically lower than in the first 10 minutes, N=29) differed from those who did not (N=11) on the MATRICS Attention/Vigilance subscale [t(37)=2.27, P<0.03].[3] For HCS, the same comparison was not significant [t(27)<1], probably due to the absence of a performance decrement over time in this group.

Medication effects

Haloperidol equivalents (Andreasen, Pressler, Nopoulos, Miller, & Ho, 2010) did not correlate with the %Hit decrement index described above (P>0.8) or average %Hits (P>0.18). Furthermore, we compared %Hit decrement and average %Hits between PSZ who did or did not receive mood stabilizing medication [t(38)<1.23, P>0.22 for each variable; independent samples t-test], or anxiolytic medication [t(38)<1], and between PSZ who received a typical vs. atypical antipsychotic [PSZ who received both were classified according to which was given at the larger haloperidol-equivalent dose; t(38)<1.4, P>0.17]. Thus, we conclude that our main results were unlikely to be secondary to or significantly influenced by current medication status.

Discussion

The ability to sustain attention to the task at hand is a prerequisite for the successful performance of many real-world activities. A sustained attention deficit could account for non-specific performance impairment across a range of experimental paradigms, and would pose a substantial limitation to everyday functions that require the ability to stay on task for extended periods of time, for example executing a sequence of contingent cognitive or behavioral steps. The question of whether or not PSZ have difficulty sustaining attention therefore is of high relevance but has not been conclusively answered in over four decades of research.

[2]In an effort to match groups on both %Hits and FAs, we repeated the analysis after first excluding the four outlier subjects mentioned under "False Alarms" that made over 75 FAs and after that the 10 of the remaining subjects with the lowest average %Hit. Three of the subjects that were excluded for FAs would also have been excluded for low %Hits; the PSZ subsample thus created therefore differed from the one described in the main text in only one subject. The new subsample of PSZ again resembled the HCS sample in %Hits in the first two time periods, but also in total FAs (PSZ: 10.6 ± 10.7; HCS: 7.6 ± 6.3; t(54)=1.27, P>0.2). The Group × Time period interaction on %Hits was significant with this PSZ subsample, as well [F(5,270)=2.58, P<0.03].

[3]Neuropsychological assessments were not obtained for one PSZ with a positive decrement index.

By following basic science taxonomy for the construct validity of sustained attention tasks, the present task paradigm was designed to be maximally sensitive to deficits in sustained attention. Using this approach, we showed a clear impairment of PSZ relative to HCS in sustaining attention over time. Even when the analysis was limited to PSZ who started off with the same average target detection rate as HCS, PSZ were unable to uphold their initial performance level and, after 10 minutes on task, started to show a significant decline that continued until the end of the 30-minute session. The finding that both groups displayed signs of a performance decrement from the first to the second 5-minute period shows that sustained attention was taxed early on. However, HCS managed to recover from this initial decline, suggesting the presence of an internal feedback mechanism that signaled the need to recruit additional resources when attention started to dwindle. This feedback mechanism appears to be dysfunctional in PSZ, suggesting a qualitative difference from HCS performance, or, alternatively, PSZ lacked sufficient additional resources needed to sustain task performance. Independent of the underlying mechanism, the present results demonstrate that PSZ have a clear deficit maintaining attention over extended periods of time when the nature of the task challenges this ability.

Average performance in the complete sample of PSZ was lower than in HCS, even at task onset. Thus, a sustained attention deficit in PSZ cannot explain signal-processing deficits in their entirety. However, the finding that the drop in %Hits in PSZ from period 1 to period 6 was of approximately the same magnitude (9.2%, Cohen’s d=0.50) as the group difference at task onset (9.1%, Cohen’s d=0.61) shows that the sustained attention deficit in PSZ is substantial.

Given the clear evidence for an impairment in sustained attention in the present study, it is worth considering why time-on-task effects have rarely been reported in other tasks, such as CPT. This is assuming an absence of performance decrements over time in most of the studies that did not report on the appropriate tests. One possibility is that in tasks with less continuous processing demands a sustained attention deficit may be more prone to manifesting itself in intermittent attentional lapses, which may provide temporary relief to the information processing system and prevent a performance decrement over time. In the current Raindrops task, 11 stimuli have to be monitored at any moment in time, and the termination of one stimulus is immediately replaced with the onset of another. These continuously high processing demands prohibit even very short periods of drifting off task, rest and recuperation. Other reasons for the predominant absence of a performance decrement in tasks such as the CPT, even in demanding versions thereof, may include a short task duration (typically 5–10 minutes), a regular stimulus presentation rate that promotes an automatic information processing mode, and generally lower processing demands that do not tax the limits of the subjects’ attentional capacity. The latter point is supported by findings that versions of the CPT in which time-on-task effects were sometimes found are those employing perceptually challenging stimuli (Mass, Wolf, Wagner, & Haasen, 2000; Nestor, Faux, McCarley, Shenton, & Sands, 1990; Nestor et al., 1991; Nuechterlein, Parasuraman, & Jiang, 1983; Park, Kim, Kim, Kim, & Lee, 2011; Sponheim, McGuire, & Stanwyck, 2006), thus meeting one of the criteria for the construct validity of sustained attention tasks (Parasuraman et al. 1987).

The %Hits decrement index was associated with the Attention/Vigilance domain of the MATRICS battery. This lends support to the validity of the MATRICS Attention/Vigilance subscale, which is based on the performance of an identical-pairs CPT, as an index that is significantly influenced by the ability to sustain attention over time. Note, however, that our sustained attention decrement measure did not correlate with other MATRICS domain scores, calling into question whether impairments in sustained attention impact neuropsychological tests in a generalized fashion. Neuropsychological measurements of

most cognitive abilities using standard clinical methods involve a fair amount of ongoing interaction between subject and tester. Examiners are likely to alter testing procedures in a variety of subtle ways to sustain the engagement of patients who are drifting off task. In essence, we would expect a deficit in sustained attention to be more evident in everyday life situations in which PSZ must sustain their behavior on the basis of internal goal representations. Indeed, it is striking that both Kraepelin (1919) and Bleuler (1911) commented on this aspect of behavior on the basis of clinical observation, whereas over four decades of experimental research had produced, at best, limited evidence in support of their observations.

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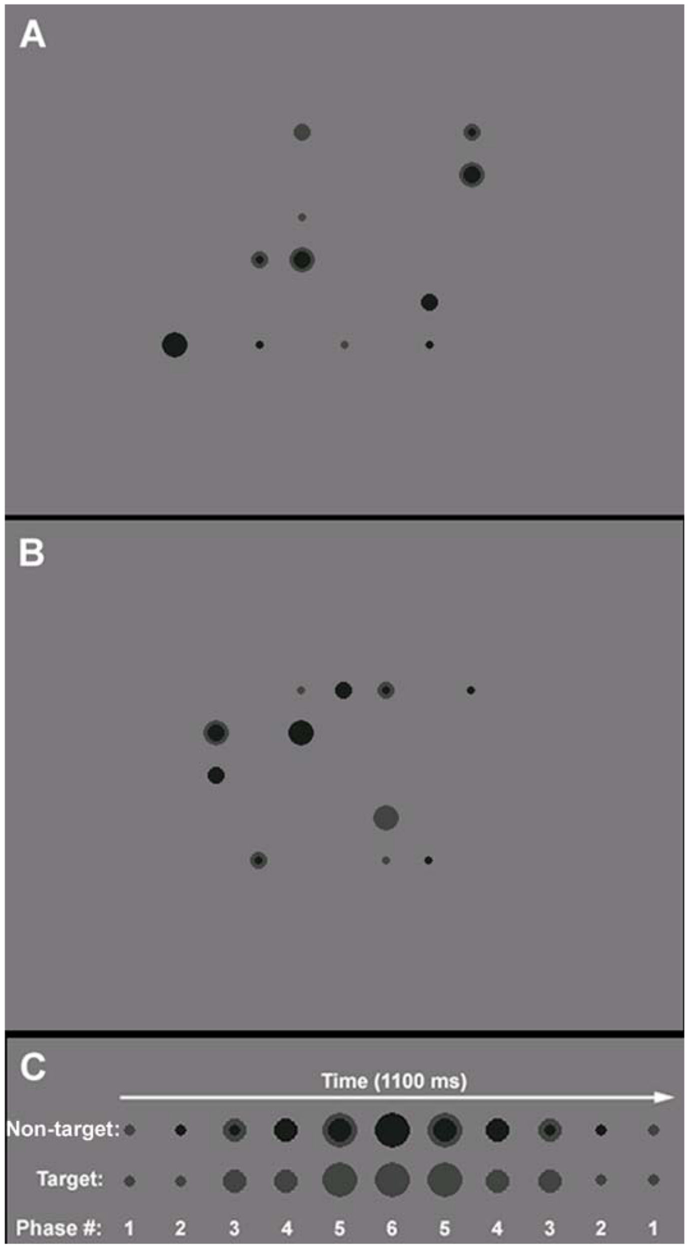

Figure 1.
Example still shots from the “Raindrops” task (panels A and B), and a sequential view of the growth and shrinkage phases that non-target and target stimuli completed over the course of their 1100-ms life span (panel C). The screen display and every stimulus thereon changed every 100 ms, creating the impression of a constant dynamic growth and shrinkage of the stimuli. A stimulus that completed all phases and disappeared was replaced by a stimulus onset in another, randomly determined location. Both panel A and panel B contain a target stimulus. In panel A, the target is in phase 3 or 4. In panel B, the target is in phase 5 or 6, in which it is the easiest to discern from a nontarget stimulus.

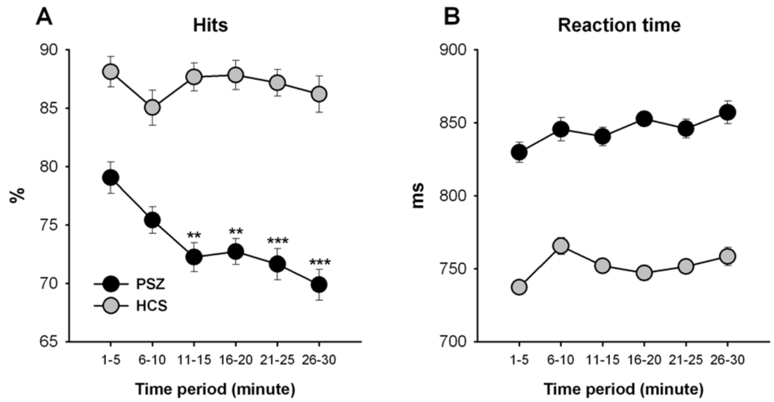

Figure 2.

The average % Hits (A) and reaction time (B) of 40 people with schizophrenia (PSZ) and 29 healthy control subjects (HCS) in each 5-min period of the 30-min Raindrops task. Error bars reflect SEMs, adjusted to remove within-group between subject variability in average %Hits across time periods (Cousineau, 2007). **P<0.01, ***P<0.001 in paired t-tests comparing performance in the second through sixth time period to performance in the first period. P-values are Bonferroni-adjusted for five comparisons.

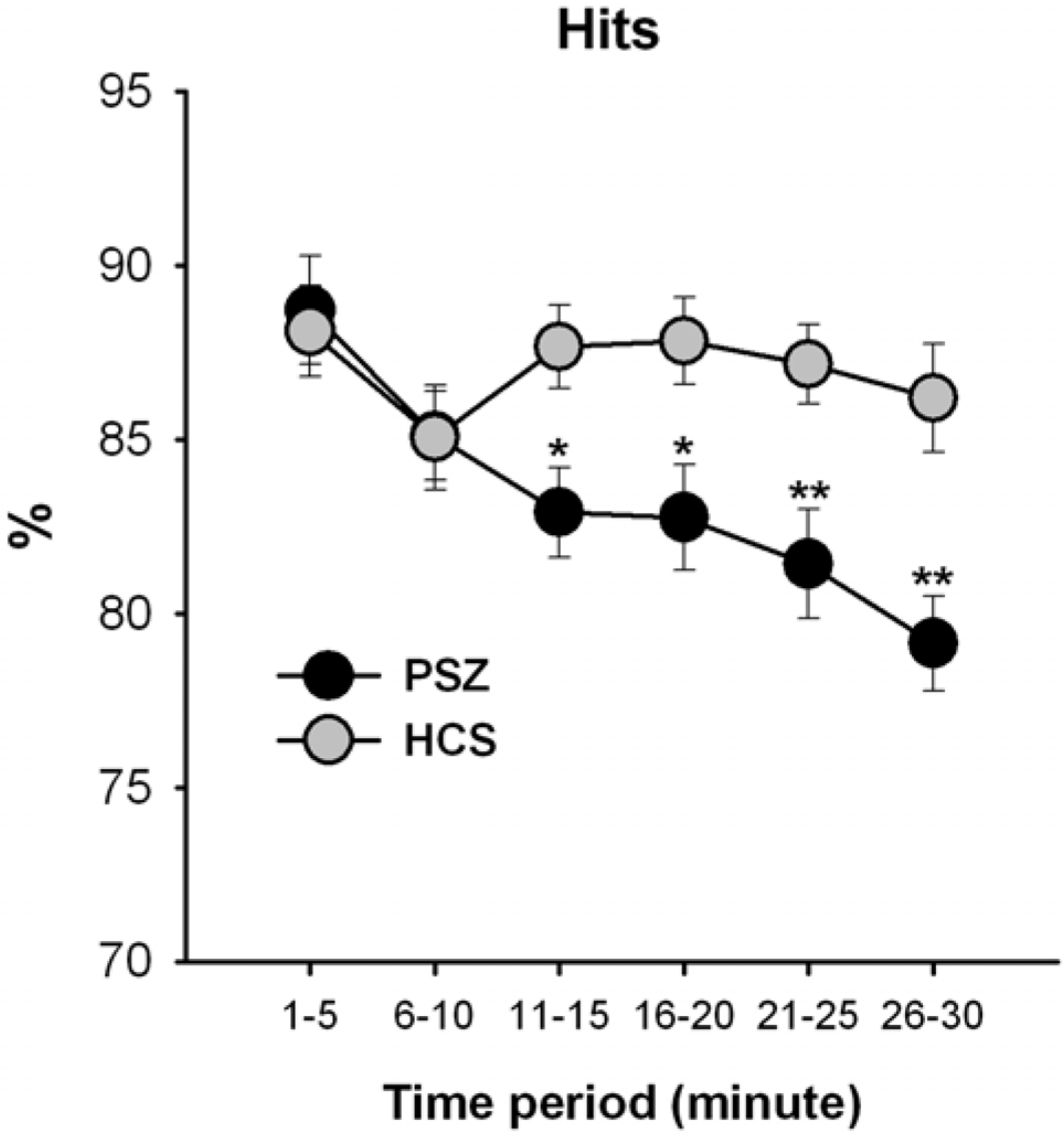

Figure 3.

The average % Hits in each 5-min task period for all 29 healthy control subjects (HCS), and 27 people with schizophrenia (PSZ) selected for displaying the highest average % Hits across the entire session. Error bars reflect SEMs, adjusted to remove within-group between-subject variability in average %Hits across time periods (Cousineau, 2007). *P<0.05, **P<0.01 in paired t-tests comparing performance in the second through sixth time period to the first period. P-values are Bonferroni-adjusted for five comparisons.

Table 1

Group Demographics (mean ± stdev)

	PSZ	HCS
Age	41.1 ± 10.6 (range 18–54)	41.4 ± 10.0 (range 19–54)
Male : Female	28 : 12	20 : 9
AA : A : C : H: O[a]	13 : 0 : 22 : 2 : 3	9 : 0 : 18 : 2 : 0
Education (years)	12.5 ± 2.5	14.8 ± 2.0***
Parental education[b]	13.3 ± 2.8[c]	13.1 ± 2.8
WASI	97.5 ± 12.0[d]	113.9 ± 12.5***
WRAT 4 standard score	95.5 ± 12.5[d]	106.1 ± 15.8**
WTAR standard score	99.9 ± 14.9[d]	108.4 ± 14.9*
MATRICS total score	31.9 ± 12.5[d]	52.8 ± 13.2***
BPRS[e] **total score**	36.0 ± 7.2 (range 23–49)	
SANS[f] **total score**	30.3 ± 12.9 (range 7–71)	
LOFS[g] **total score**	21.5 ± 5.2 (range 11–30)	
CDS[h] **total score**	2.4 ± 3.2 (range 0–14)	

[a]AA = African American; A = Asian; C = Caucasian; H = Hispanic; O = Other

[b]average over mother’s and father’s years of education

[c]data unavailable for 2 subjects

[d]data unavailable for 1 subject

*P<0.05,

**P<0.01,

***P<0.001; significant difference between PSZ and HCS in independent samples t-test

[e]Brief Psychiatric Rating Scale (Overall & Gorman, 1962)

[f]Scale for the Assessment of Negative Symptoms (Andreasen, 1984)

[g]Level Of Functioning Scale (Hawk, Carpenter, Jr., & Strauss, 1975)

[h]Calgary Depression Scale (Addington, Addington, Maticka-Tyndale, & Joyce, 1992)