Cogn Process (2013) 14:273–281
DOI 10.1007/s10339-013-0553-5

RESEARCH REPORT

Attentional blink and impulsiveness: evidence for higher functional impulsivity in non-blinkers compared to blinkers

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Received: 29 August 2012 / Accepted: 14 February 2013 / Published online: 28 February 2013

Abstract The attentional blink (AB) represents a fundamental limit of information processing. About 5–10 % of all subjects, however, do not show the AB. Because of the low base rate of these so-called non-blinkers, studies on mechanisms underlying non-blinkers' absent AB are extremely scant. The few existent studies found non-blinkers to be faster and more efficient in information processing compared to blinkers. A personality trait that has been linked previously to speed and efficiency of information processing as well as to the magnitude of the AB is impulsivity. Therefore, the present study investigated whether 15 non-blinkers and 15 blinkers differed from each other in functional and/or dysfunctional impulsivity. To obtain a better understanding of the underlying processing mechanisms, the P300 component in the event-related potential was recorded during performance on the AB task. Our results indicated higher functional impulsivity in non-blinkers compared to blinkers but no differences between the two groups in dysfunctional impulsivity. As indicated by shorter P300 latency, non-blinkers processed information faster than blinkers after the AB period but slower during the AB period. These speed effects, however, were not associated with functional impulsivity. Thus, impulsivity and speed of information processing appear to represent two rather independent sources for non-blinkers' absent AB.

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Introduction

Within a rapid serial visual presentation (RSVP) of stimuli, the identification of a second of two targets (T2) is impaired severely when presented about 150–350 ms after the first target (T1). This well-established phenomenon, referred to as the attentional blink (AB), has been subject of innumerous studies investigating the conditions and underpinnings of its occurrence (cf., Martens and Wyble 2010). According to an integrating explanation of the AB by Dux and Marois (2009), all stimuli in the RSVP are analyzed at an initial perceptual and conceptual level of information processing. In accordance with the task instructions, an attentional set is established enhancing the mental representation of T1 and inhibiting mental representations of distractor stimuli during an attentional episode. As the attentional episode lasts longer than the presentation of T1, also the subsequent stimuli are attentionally enhanced and compete with T1 for higher order processing. T1, however, is more task-relevant and presented earlier than the subsequent distractor stimuli so that it gathers the resources for episodic registration and consolidation in working memory (WM) to be properly identified. These latter processes require attentional resources so that mental representations of stimuli presented during the attentional episode of T1 cannot be attentionally enhanced (Bowman and Wyble 2007). Thus, if T2 is presented during this period of time, its mental representation is prone to rapid decay leading to the AB phenomenon. As an exception, T2 can be identified quite well when it is presented immediately after T1 probably because it slips in the same attentional episode as T1 (Akyürek et al. 2012).

Only less than 10 % of all subjects do not show an AB but constantly good performance on AB tasks—irrespective of the lag with which T2 is presented after T1 (Martens et al.

2010). Given the rather small base rate of so-called non-blinkers, studies investigating reasons for the difference between blinkers (i.e., individuals who show the AB) and non-blinkers are scant (for an overview see Martens and Wyble 2010). Experimental and psychophysiological studies by Martens and colleagues indicated more efficient ignoring of distractors and better extraction of target-related information in non-blinkers compared to blinkers (Martens et al. 2006, 2010; Martens and Valchev 2009). The more efficient extraction of target-related information, for example, was evident in non-blinkers' larger frontal selection positivity which is a component of the event-related potential (ERP) associated with the selection of target features (Martens et al. 2006). Feinstein et al.'s (2004) results point into a similar direction. These authors used functional magnetic resonance imaging while participants performed an AB task. Non-blinkers exhibited more activation in the medial prefrontal cortex, the frontopolar cortex, and the anterior cingulate compared to blinkers indicating that attentional networks in these areas are more efficiently used by non-blinkers. According to Martens et al. (2006), more efficient information processing in non-blinkers leads to a shorter T2-related P300 latency in the event-related potential (ERP). As the P300 component seems to indicate the consolidation of a stimulus' mental representation in WM (e.g., Donchin and Coles 1988), non-blinkers' shorter T2-related P300 latencies suggest faster consolidation of T2 in WM due to more efficient selection of targets among distractors (Martens et al. 2006). It should be noted that the T2-related P300 component is of particular interest in studying the AB since its amplitude—paralleling the identification rate—has been found to be markedly decreased when T2 is presented 150–350 ms after T1 (Vogel et al. 1998).

Martens et al. (2006) also reported the lacking AB in non-blinkers to be consistent across testing sessions. Therefore, the absent AB can be considered a stable trait rather than a state variable. Proceeding from this view, the lacking AB might be related to a personality traits modulating information processing. A promising candidate for such a trait is impulsivity as high and low impulsives are well-known to differ from each other in information processing. Previous reports highlighted difficulties in sustained attention and less efficient inhibition of task-irrelevant information in individuals with high impulsivity (Dickman 2000; Marsh et al. 2002; Russo et al. 2008). In line with these findings, Li et al. (2005) found a more pronounced AB in individuals with higher impulsivity and explained this more limited information processing by less efficient and less dynamic processing mechanisms. Hence, low individual levels of impulsivity may be related to the absent AB in non-blinkers.

Within the field of research on cognitive functioning and impulsivity, Dickman (1990) introduced the differentiation between dysfunctional and functional impulsivity. *Dysfunctional impulsivity* is defined as the "tendency to act with less forethought than most people of equal ability when this tendency is a source of difficulty" while *functional impulsivity* refers to the "tendency to act with relatively little forethought when such a style is optimal" (Dickman 1990, p. 95). Several studies provide converging evidence for the notion of less accurate information processing and higher cognitive distortion in high dysfunctional impulsivity (Brunas-Wagstaff et al. 1994, 1996; Mobini et al. 2007). Functional impulsivity, on the contrary, is associated with higher speed of information processing which can lead to more efficient processing (Brunas-Wagstaff et al. 1994, 1996; Dickman 1990, 2000; Reeve 2007). According to Dickman (1993), high functional impulsives produce more responses due to their faster speed of information processing. This higher amount of responses consists of more incorrect but also more correct responses with the higher number of correct responses compensating for the elevated error rate resulting in higher efficiency of information processing.

Differentiating between functional and dysfunctional impulsivity, it appears reasonable to assume that Li et al.'s (2005) finding of a more pronounced AB in high impulsives can be considered a consequence of their higher dysfunctional (rather than functional) impulsivity. This assumption is corroborated by the fact that Li et al. (2005) used the Barratt Impulsiveness Scale (BIS) to assess impulsivity. The BIS is associated mainly with dysfunctional but only marginally with functional impulsivity (Caci et al. 2003). If low dysfunctional impulsivity results in a less pronounced AB, it may also differentiate between blinkers and non-blinkers.

The question of whether there is also an association between functional impulsivity and the magnitude of the AB is still to be answered. Given the higher speed of information processing in individuals with high compared to low functional impulsivity (e.g., Brunas-Wagstaff et al. 1994; Dickman 1990) as well as in non-blinkers compared to blinkers (Martens et al. 2006), non-blinkers might be expected to be more functionally impulsive compared to blinkers.

Only few studies compared non-blinkers and blinkers (Feinstein et al. 2004; Martens et al. 2006, 2010; Martens and Valchev 2009; Martens and Wyble 2010) and only one study appears to exist on the relation between impulsivity and the AB (Li et al. 2005). Therefore, the present study was designed to systematically investigate differences in functional and dysfunctional impulsivity between blinkers and non-blinkers. For this purpose, we identified a group of non-blinkers within a large sample of participants and compared their functional and dysfunctional impulsivity scores with a group of blinkers. In order to link our results to previous findings of non-blinkers' faster information processing in terms of a shorter P300 latency (Martens et al. 2006, 2010), we also measured the P300 component during participants' performance on the AB task.

Methods

Participants

From a pool of 201 female university students, we identified 15 non-blinkers (for the criteria see below). These 15 non-blinkers were contrasted with 15 blinkers who showed the largest AB. Mean age (±standard deviation) was 21.3 (±2.8) and 21.6 (±2.7) years for non-blinkers and blinkers, respectively. To prevent sex-related variance in evoked potentials (cf., Cahill and Polich 1992; Deldin et al. 1994; Gurrera et al. 2005; Hoffman and Polich 1999) as well as in functional and dysfunctional impulsivity (cf., Adan et al. 2010; Cross et al. 2011; Vigil-Colet et al. 2008), only women were included in the present study. The study was approved by the local ethics committee, and written informed consent was obtained from all participants.

Dickman's Impulsivity Inventory (DII)

For psychometric assessment of functional and dysfunctional impulsivity, participants filled in the German adaptation (Kuhmann and Ising 1996) of the DII (Dickman 1990). The scale Functional Impulsivity consisted of 11 items ($\alpha = .74$), and the scale Dysfunctional Impulsivity consisted of 12 items ($\alpha = .85$).

Attentional blink task

Apparatus and stimuli

Stimulus presentation and response collection was controlled by E-prime 2.0 experimental software. A chin rest was used to ensure constant posture of participants' head. Stimuli were the letters of the alphabet as well as the digit "2" (which was T2). The letters F, I, K, Q, and Z were not used because of their similarity with other letters (e.g., E, J, R, O) or, in case of the letter "Z", the similarity with the digit "2". All stimuli were presented in white against a black background, only T1 was presented in yellow (RGB as preset by E-prime). Each stimulus subtended 3.01° of visual angle vertically and about 2.01° horizontally and was presented in the center of the monitor screen.

Procedure

Testing took place in a sound-attenuated and electrically shielded room. The task consisted of 240 trials each starting with a fixation cross presented for a duration varying randomly between 1,000 and 1,250 ms. After the fixation cross disappeared, 15 stimuli were presented successively for 100 ms each without interstimulus interval. T1 occurred at the fourth or seventh position in 50 % of the trials, respectively. In 75 % of the trials, T2 was the first, second, third, fourth, or fifth character after T1 (referred to as Lag 1, Lag 2, Lag, 3, Lag 4, or Lag 5) with the same probability for each position. Positions of T1 and T2 were randomized across trials. Immediately after the stream of stimuli, participants' task was to decide whether the yellow letter (T1) was a vowel or a consonant and, after they have responded this question, whether the digit "2" (T2) had been presented or not. Participants answered the two questions by pressing one of two designated keys on a response panel with the forefingers of the right and left hand, respectively. Rate of correct T1 and T2 identifications were computed for each lag condition. Only trials with correct responses to T1 were further analyzed.

Non-blinkers were defined by showing an AB of less than 10 % according to the following formula (Martens et al. 2006): {[(T1 accuracy at Lag 2 − T2|T1 accuracy at Lag 2)/T1 accuracy at Lag 2] + [(T1 accuracy at Lag 3 − T2|T1 accuracy at Lag 3)/T1 accuracy at Lag 3]/2} × 100. To rule out that strategy differences caused the absent AB, a second criterion was that non-blinkers did not only show no AB on T2 but also no decrement of T1 performance across the five lag conditions. These 15 non-blinkers were contrasted with 15 blinkers who showed the largest AB according to the mentioned formula. As in the study by Martens et al. (2006), mean T1 accuracy across all trials was at least 80 % in all included participants.

Electrophysiological recordings

EEG activity was recorded by a BrainAmp® amplifier and an electrode cap (EasyCap®) with Ag/AgCl electrodes. We used electrodes at Fz, Cz, Pz, Oz, C3, C4, P3, P4, T7, T8 and referenced them to the ear lobes. To measure the electrooculogram (EOG), two electrodes were placed about 1 cm from the outer canthi of each eye (horizontal EOG) and on the supra- and infraorbital ridges of the right eye (vertical EOG). Electrode impedance was lower than 5 kΩ.

EEG and EOG were digitized at a rate of 1,000 Hz and off-line filtered (0.5–20 Hz). The data were visually inspected for movement artifacts. Afterward, the impact of eye movements was reduced by the regression-based method as proposed by Gratton et al. (1983). Single-trial epochs were built with a prestimulus interval of 200 ms and a 1,500-ms interval following the onset of T1. All epochs were again screened for artifacts using an automatic procedure marking suspicious epochs. These were again visually inspected. Only artifact-free epochs were averaged separately for the five lag conditions as well as for trials with no T2 presentation. On average, there were 30.1, 29.1, 29.7, 31.6, and 30.4 artifact-free epochs for the five lag conditions.

In a next step, the average wave of trials without T2 presentation was subtracted from the average waves of trials with T2 presentation to reduce the influence of T1-related activity on the ERP. Thus, the resulting five difference waves are assumed to consist of activity mainly related to the processing of T2 (Luck 2005). Separately for each group, grand averages (GAs) were computed for each lag condition. P300 amplitude was quantified as the area under the curve ranging ±50 ms around the maximum peak in the GA. P300 latency was the point dividing the area into two equal regions.

Results

Behavioral data

Mean T1 identification rate (±standard error of the mean; SEM) across the five lag conditions was 0.94 (±0.01) and 0.93 (±0.01) in non-blinkers and blinkers, respectively. The difference was not statistically significant [$t(28) = .51$; $p = .62$]. Thus, differences in T1 identification rate between the two groups can be ruled out to account for differences in the magnitude of the AB (cf., Arnell et al. 2006).

Means and SEM for correct T2 identification in the five lag conditions and scores on the DII scales are presented in Table 1 for blinkers and non-blinkers, respectively. A two-way analysis of variance (ANOVA) was calculated on the T2 identification rate with *Group* (blinkers and non-blinkers) as a between-subject factor and the five lag conditions as five levels of a repeated-measures factor *Lag*. As can be seen from Fig. 1, across all lags, non-blinkers outperformed blinkers [$F(1,28) = 190.40$; $p < .001$; $\eta_p^2 = .87$] with a mean rate of correct T2 identification of 0.94 ± 0.02 and 0.64 ± 0.02 in non-blinkers and blinkers, respectively. Also, the main effect Lag [$F(4,112) = 71.62$; $p < .001$; $\eta_p^2 = .72$] as well as the interaction between Lag and Group yielded statistical significance [$F(4,112) = 61.70$; $p < .001$; $\eta_p^2 = .69$]. Scheffé tests revealed that non-blinkers' performance did not vary significantly as a function of lag condition (all *ps* > .95). The performance of blinkers in the Lag 2 and Lag 3 conditions was significantly worse compared to the other three lag conditions (all *ps* < .001). Non-blinkers showed better T2-identification compared to blinkers in the Lag 2 and Lag 3 conditions (both *ps* < .001) but not in the Lag 1 ($p = .92$), Lag 4 ($p = .69$), and Lag 5 conditions ($p = .59$). Thus, as expected due to our selection criteria, the group of blinkers but not the group of non-blinkers exhibited a reliable AB on the present task.

Behavioral data and impulsivity

As depicted in Fig. 2, non-blinkers did not differ significantly from blinkers in dysfunctional impulsivity [$t(28) = -.07$; $p = .94$; $d = -.02$] but scored significantly higher than blinkers in functional impulsivity [$t(28) = 2.60$; $p < .01$; $d = .95$]. To investigate this group difference in more detail, we calculated Spearman rank correlations between T2 identification rate and impulsivity scores (see Table 2). This correlational analysis revealed that—within the two groups of blinkers and non-blinkers, respectively—only non-blinkers' correlation between dysfunctional impulsivity and correct T2 identification in the Lag 5 condition reached statistical significance. As there was no consistent pattern across the lag conditions and as we did not control for alpha inflation, this correlation might

Table 1 Mean (*M*) and standard errors of mean (SEM) of correct T2 identification, P300 amplitude and latency in the five lag conditions as well as functional and dysfunctional impulsivity scores in 15 blinkers and 15 non-blinkers, respectively

	Blinkers		Non-blinkers	
	M	SEM	*M*	SEM
T2 identification rate				
Lag 1	0.85	0.03	0.95	0.01
Lag 2	0.31	0.04	0.94	0.01
Lag 3	0.38	0.04	0.92	0.01
Lag 4	0.83	0.03	0.96	0.01
Lag 5	0.81	0.03	0.94	0.01
P300 amplitude (μV)				
Lag 1	239	24	288	36
Lag 2	153	16	238	41
Lag 3	202	26	284	40
Lag 4	317	37	380	40
Lag 5	404	38	418	58
P300 latency (ms)				
Lag 1	525	5	510	3
Lag 2	432	4	475	4
Lag 3	466	4	511	4
Lag 4	569	4	480	3
Lag 5	480	3	453	2
Impulsivity scores				
Functional Impulsivity	3.00	0.62	5.73	0.85
Dysfunctional Impulsivity	2.73	0.79	2.67	0.58

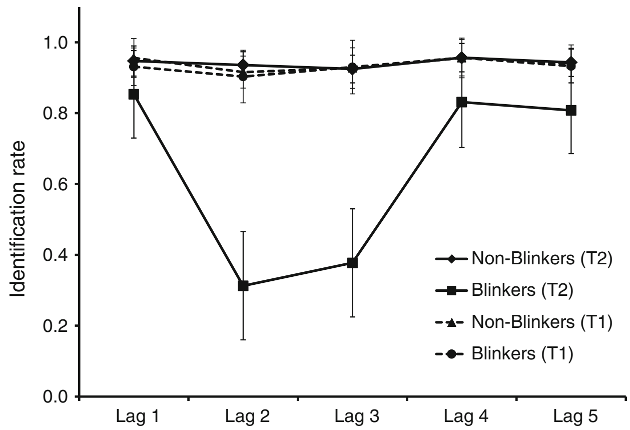

Fig. 1 Blinkers' ($n = 15$) and non-blinkers' ($n = 15$) mean T1 and T2|T1 identification rate (±standard deviation) in the five lag conditions of the AB task

be due to chance rather than indicating a reliable functional relationship. Across the two groups combined, however, functional impulsivity was significantly correlated with T2 identification in all lag conditions except for the Lag 1 condition where the correlation just failed to reach statistical significance ($p = .08$).

Electrophysiological data

Blinkers' and non-blinkers' ERP waveforms referring to T2 identification in the five lag conditions are given in Fig. 3. Means and SEM for P300 latency and amplitude in the five lag conditions are presented in Table 1. An ANOVA with P300 latency as dependent variable revealed a statistically significant effect of Group [$F(1,28) = 10.2$; $p < .01$; $\eta_p^2 = .27$] with non-blinkers showing shorter latencies (486 ± 2 ms) than blinkers (494 ± 2 ms) across all lags. This result supports Martens et al.'s (2006) finding of higher

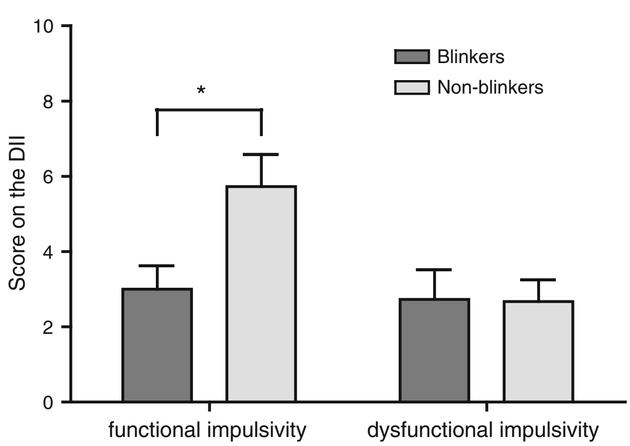

Fig. 2 Functional and dysfunctional impulsivity in 15 blinkers and 15 non-blinkers. *$p < .05$

Table 2 Spearman's rank correlations between functional and dysfunction impulsivity and T2 identification rate as well as T2-related P300 amplitude and latency in the five lag conditions in 15 blinkers and 15 non-blinkers

	Functional impulsivity			Dysfunctional impulsivity		
	Blinkers	Non-blinkers	All	Blinkers	Non-blinkers	All
T2 identification rate						
Lag 1	−0.01	0.29	0.32	0.32	−0.29	0.12
Lag 2	−0.20	0.15	0.40*	−0.07	−0.38	−0.04
Lag 3	0.41	−0.21	0.42*	0.21	0.13	0.15
Lag 4	0.16	0.37	0.41*	0.23	0.01	0.17
Lag 5	0.25	0.42	0.55**	0.08	0.55*	0.24
P300 amplitude						
Lag 1	−0.67**	0.04	0.06	0.07	0.08	0.09
Lag 2	−0.17	0.08	−0.08	−0.32	−0.07	−0.17
Lag 3	0.29	0.34	0.43**	−0.09	0.47	0.14
Lag 4	0.02	0.28	0.12	−0.57*	−0.09	−0.08
Lag 5	−0.12	0.28	0.07	−0.39	0.13	−0.08
P300 latency						
Lag 1	0.25	0.41	0.04	0.03	0.13	0.08
Lag 2	−0.08	0.28	0.10	−0.28	−0.07	0.01
Lag 3	0.25	0.20	0.13	−0.47	0.36	0.10
Lag 4	−0.51	−0.07	−0.51**	0.14	0.29	0.00
Lag 5	0.02	0.46	−0.12	−0.76	0.46	−0.36

* $p < .05$; ** $p < .01$

speed of information processing in non-blinkers compared to blinkers. Also, the main effect of Lag [$F(4,112) = 174.6$; $p < .001$; $\eta_p^2 = .86$] and the interaction between Lag and Group were significant [$F(4,112) = 140.7$; $p < .001$; $\eta_p^2 = .83$]. As indicated by post hoc Scheffé tests, non-blinkers' P300 latencies in the five lag conditions differed significantly from each other (all $ps < .05$). Only P300 latencies in the Lag 1 and in the Lag 3 condition as well as P300 latencies in the Lag 2 and in the Lag 4 condition did not differ from each other (both $ps = .99$). Also in blinkers, the differences between the P300 latencies in the five lag conditions were statistically significant (all $ps < .001$) except for the latencies in the Lag 3 and 5 conditions ($p = .55$). Comparisons between the two groups revealed no significant difference in the Lag 1 condition ($p = .72$). Non-blinkers exhibited longer P300 latencies in the Lag 2 and Lag 3 conditions (both ps $< .001$) but shorter latencies in the Lag 4 ($p < .001$) and Lag 5 conditions ($p < .05$) compared to blinkers.

For P300 amplitude, the effect of Group was not statistically significant [$F(1,28) = 3.36$; $p = .08$; $\eta_p^2 = .11$]. The statistical significance of Lag [$F(4,112) = 13.53$; $p < .001$; $\eta_p^2 = .33$] was due to the fact that P300 amplitude in the Lag 5 condition was significantly larger than in the Lag 1 ($p < .001$), Lag 2 ($p < .001$), and Lag 3 conditions ($p < .001$) and that the P300 amplitude in the Lag 4 condition was significantly larger than in the Lag 2 ($p < .001$) and Lag 3 conditions ($p < .05$). All other comparisons failed to reach statistical significance. There was no significant interaction effect [$F(4,112) = .38$; $p = .82$; $\eta_p^2 = .02$].

Electrophysiological data and impulsivity

In blinkers, P300 amplitude was negatively related to dysfunctional impulsivity in the Lag 4 condition and to functional impulsivity in the Lag 1 condition (see Table 2). Furthermore, across the two groups combined, functional impulsivity was positively related to P300 amplitude in the Lag 3 condition ($p < .01$) and negatively to P300 latency in the Lag 5 condition ($p < .01$). Given this highly inconsistent pattern of results and uncontrolled alpha inflation, this correlational analysis did not support the assumption of a functional relationship between AB-related P300 amplitude and/or latency and impulsivity in the present study.

Discussion

The present study found non-blinkers to be more functionally impulsive than blinkers but no group differences regarding dysfunctional impulsivity. Furthermore, in line with previous reports (Martens et al. 2006), non-blinkers exhibited shorter P300 latencies across all five lag conditions. This main effect, however, was due to the lag conditions after the AB period. During the AB period, that is, in the Lag 2 and Lag 3 conditions, blinkers showed faster P300 latencies compared to non-blinkers. The ERP measures were not associated with functional or dysfunctional impulsivity.

Higher functional, but not dysfunctional, impulsivity was observed in non-blinkers compared to blinkers. Furthermore, across both groups, T2 identification rate was positively related to functional but not dysfunctional impulsivity in virtually all lag conditions. This result supports Dickman's (1990) assumption that these two aspects of impulsivity are differentially related to information processing. Dickman (1993) proposed high functional impulsivity to be associated with better performance in situations when a rapid, inaccurate style of processing is instrumental and conducive. The AB seems to represent such a situation as non-blinkers were—by definition—the better performers and, concurrently, more functionally impulsive compared to blinkers. In light of Martens et al.'s (2006) observation that, in non-blinkers, the absence of an AB is stable across testing sessions, our results suggest a characteristic processing style in non-blinkers associated with functional impulsivity.

In contrast to functional impulsivity, levels of dysfunctional impulsivity did not differ between blinkers and non-blinkers. This result was somewhat surprising against the background of Li et al.'s (2005) finding of a larger AB in high compared to low impulsives. Proceeding from this finding, lower dysfunctional impulsivity in non-blinkers than in blinkers would have been the expected outcome. It should be noted, however, that, unlike the present study, Li et al. (2005) did not compare individual levels of impulsivity in blinkers and non-blinkers. Rather, they contrasted magnitude of the AB in high, intermediate, and low impulsives with none of these groups completely lacking the

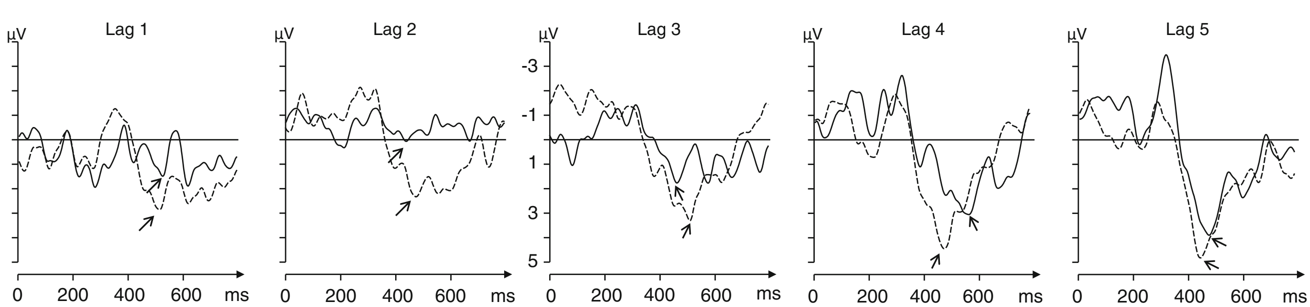

Fig. 3 T2-related ERPs at Pz electrode site in 15 blinkers (*solid line*) and 15 non-blinkers (*dotted line*) in the five lag conditions. The waveforms are baseline corrected to the 200-ms interval prior to the onset of T1. For reasons of clarity, the *zero points* in this figure refer to the onset of T2. *Negative* is *plotted upwards* and *arrows* indicate the P300 amplitude

AB. Furthermore, Li et al. (2005) used the BIS as a measure of impulsivity, whereas, in the present study, the DII was applied to dissociate functional and dysfunctional aspects of impulsivity. These two major differences between Li et al.'s (2005) and the present experimental design could have contributed to the divergent findings.

Our electrophysiological data confirmed previous reports of a decreased P300 amplitude during the attentional episode of T1 (e.g., Vogel et al. 1998). Most interestingly, however, the main effect of Lag was not mediated by the group factor (i.e., blinkers vs. non-blinkers). Also in non-blinkers, P300 amplitude varied as a function of lag condition. Thus, our findings suggest that the process reflected by the P300 component cannot completely account for the AB. Obviously, more processes than only one appear to be involved in the AB as also indicated by previous research (Dux and Marois 2009; Kawahara et al. 2006; Troche et al. 2009).

Nevertheless, across all lag conditions, non-blinkers compared to blinkers exhibited shorter P300 latencies indicating faster speed of information consolidation in WM (cf., Beauchamp and Stelmack 2006). This interpretation is in line with Martens et al.'s (2006) conclusion that non-blinkers ignore distractors and extract target-related information more efficiently during the RSVP. The effect, however, was restricted to the Lag 4 and Lag 5 conditions, that is, when T2 was presented after the AB period. In the Lag 2 and Lag 3 conditions, non-blinkers exhibited longer P300 latencies compared to blinkers. This finding is in contrast to Martens et al.'s (2006) report of non-blinkers' shorter P300 latencies during the AB period. While Martens et al. (2006) analyzed only trials in which both T1 and T2 were correctly identified by blinkers and non-blinkers, P300 latencies in the present study were based on both blink and non-blink trials, that is, trials on which T1 and T2 or only T1 were correctly identified. A separate analysis of non-blink trials was not possible due to the low number of non-blink trials in our sample of blinkers in the Lag 2 and Lag 3 conditions (cf., Cohen and Polich 1997). The high number of blink trials in the Lag 2 and Lag 3 conditions in blinkers, as compared to non-blinkers, may have led to the disparity between our and Martens et al.'s (2006) findings. This conclusion would be consistent with the finding of non-blinkers' shorter latencies in the Lag 4 and Lag 5 conditions where almost all trials were non-blink trials in both groups. It should be noted that the P300 component was clearly observable also in blinkers despite of the high number of blink trials in the Lag 2 and Lag 3 conditions. Thus, it is unlikely that a lower signal-to-noise ratio accounted artificially for the finding of shorter P300 latencies in blinkers compared to non-blinkers during the AB period. A tentative explanation of the shorter latencies might be that blinkers identified the P300 component rather infrequently so that T2 elicited a kind of novelty P300 (cf., Polich 2007). Such an early component might have merged with the later P300 component and biased the overall latency. This explanation, however, is highly speculative and further research is needed to investigate possible reasons for blinkers' shorter latencies during the AB period.

In none of the five lag conditions, P300 amplitude or latency was reliably related to dysfunctional impulsivity. Higher speed of information processing has been previously reported in individuals with high compared to low functional impulsivity (e.g., Brunas-Wagstaff et al. 1994; Dickman 1990). A similar speed advantage could not be observed for P300 latencies in the present study. It is noteworthy that these previous findings of higher speed of information processing in high functionally impulsive individuals were based primarily on reaction time (RT) measures. RT, however, is influenced by other underlying processes compared to the P300 latency (Doucet and Stelmack 1999; McCarthy and Donchin 1981). Hence, our finding that functional impulsivity and P300 latency were not associated is not in sharp contrast to reports of shorter RTs in high functional impulsivity.

As speed of processing does not explain higher functional impulsivity in non-blinkers compared to blinkers, we can only speculate on the underlying mechanisms. A possible explanation might be derived from Olivers and Nieuwenhuis' (2006) overinvestment hypothesis. According to this hypothesis, the AB is the result of an overinvestment of attentional resources. Participants are instructed to concentrate on the string of items, and they try hard to focus on the items. As a consequence, not only targets but also distractor stimuli are attentionally enhanced for further cognitive processing. During this processing, the attentionally enhanced distractors interfere with targets leading to the AB. In line with this idea, Olivers and Nieuwenhuis (2006) reported a less pronounced AB when participants invested less focused attention on the stimuli (for similar results see Taatgen et al. 2009; Wierda et al. 2010). Within the framework of the overinvestment hypothesis, it is conceivable that non-blinkers spend less attentional resources on stimulus processing leading to their completely lacking AB. Higher functional impulsivity could contribute to such a style of information processing since, according to Dickman's attentional-fixity theory, high impulsives have difficulties in fixing their attention on the source of input (Dickman 1993, 2000). Similarly, Kirkeby and Robinson (2005) provided empirical evidence for the notion that high impulsives' responses are more reflexively triggered by stimuli and that they show less cognitive mediational activity between stimulus and response. Thus, both Dickman (2000) as well as Kirkeby and Robinson (2005) assume less focused attention in high impulsive individuals. This may result in a less pronounced AB as predicted by Olivers and Nieuwenhuis' (2006) overinvestment theory. This post hoc explanation, however, is somewhat limited as Dickman's (2000) attentional-fixity theory as well as Kirkeby and Robinson's (2005) hypothesis of a more reflexive style of information processing in high impulsives refer more or less explicitly to dysfunctional rather than functional impulsivity.

Finally, it should be mentioned that there is good evidence for moderate sex differences in functional impulsivity (Cross et al. 2011) as well as in P300 amplitude and latency (Deldin et al. 1994; Hoffman and Polich 1999). As our sample consisted of only female participants, it remains unclear whether our results would also hold for men. Therefore, further investigations are needed on the processing mechanisms associated with non-blinkers' higher functional impulsivity.

Acknowledgments This work was supported by the Swiss National Science Foundation (Grant No. 105314-120096).

References

Adan A, Natale V, Caci H, Prat G (2010) Relationship between circadian typology and functional and dysfunctional impulsivity. Chronobiol Int 27:606–619

Akyürek EG, Eshuis SAH, Nieuwenstein MR, Saija JD, Başkent D, Hommel B (2012) Temporal target integration underlies performance at lag 1 in the attentional blink. J Exp Psychol Hum Percept Perform. Advance online publication. doi:10.1037/a0027610

Arnell KM, Howe AE, Joanisse MF, Klein RM (2006) Relationships between attentional blink magnitude, RSVP target accuracy, and performance on other cognitive tasks. Mem Cogn 34:1472–1483

Beauchamp CM, Stelmack RM (2006) The chronometry of mental ability: an event-related potential analysis of an auditory oddball discrimination task. Intelligence 34:571–586

Bowman H, Wyble B (2007) The simultaneous type, serial token model of temporal attention and working memory. Psychol Rev 114:38–70

Brunas-Wagstaff J, Bergquist A, Wagstaff GF (1994) Cognitive correlates of functional and dysfunctional impulsivity. Personal Individ Differ 17:289–292

Brunas-Wagstaff J, Bergquist A, Morgan K, Wagstaff GF (1996) Impulsivity, interference on perceptual tasks and hypothesis testing. Personal Individ Differ 20:471–482

Caci H, Nadalet L, Baylé FJ, Robert P, Boyer P (2003) Functional and dysfunctional impulsivity: contribution to the construct validity. Acta Psychiatr Scand 107:34–40

Cahill JM, Polich J (1992) P300, probability, and introverted/extroverted personality types. Biol Psychol 33:23–35

Cohen J, Polich J (1997) On the number of trials needed for P300. Int J Psychophysiol 25:249–255

Cross CP, Copping LT, Campbell A (2011) Sex differences in impulsivity: a meta-analysis. Psychol Bull 137:97–130

Deldin PJ, Duncan CC, Miller GA (1994) Season, gender, and P300. Biol Psychol 38:15–28

Dickman SJ (1990) Functional and dysfunctional impulsivity: personality and cognitive correlates. J Pers Soc Psychol 58:95–102

Dickman SJ (1993) Impulsivity and information processing. In: McCown WG, Johnson JL, Shure MB (eds) The impulsive client: theory, research and treatment. American Psychological Association, Washington, DC

Dickman SJ (2000) Impulsivity, arousal and attention. Personal Individ Differ 28:563–581

Donchin E, Coles MGH (1988) Is the P300 component a manifestation of context updating? Behav Brain Sci 11:357–374

Doucet C, Stelmack RM (1999) The effect of response execution on P3 latency, reaction time, and movement time. Psychophysiology 36:351–363

Dux PE, Marois R (2009) The attentional blink: a review of data and theory. Atten Percept Psychophys 71:1683–1700

Feinstein JS, Stein MB, Castillo GN, Paulus MP (2004) From sensory processes to conscious perception. Conscious cogn 13:323–335

Gratton G, Coles MG, Donchin E (1983) A new method for off-line removal of ocular artifact. Electroencephalogr Clin Neurophysiol 55:468–484

Gurrera RJ, Salisbury DF, O'Donnell BF, Nestor PG, McCarley RW (2005) Auditory P3 indexes personality traits and cognitive function in healthy men and women. Psychiatry Res 133:215–228

Hoffman LD, Polich J (1999) P300, handedness, and corpus callosal size: gender, modality, and task. Int J Psychophysiol 31:163–174

Kawahara J, Enns JT, Di Lollo V (2006) The attentional blink is not a unitary phenomenon. Psychol Res 70:405–413

Kirkeby BS, Robinson MD (2005) Impulsive behavior and stimulus-response variability in choice reaction time. J Res Pers 39:263–277

Kuhmann W, Ising M (1996) Dickman Impulsivitätsskala (DIS) (technical report). Institut für Psychologie der Pädagogischen Hochschule, Erfurt

Li C-SR, Chen S-H, Lin W-H, Yang YY (2005) Attentional blink in adolescents with varying levels of impulsivity. J Psychiatr Res 39:197–205

Luck SJ (2005) An introduction to the event-related potential technique. The MIT Press, Cambridge

Marsh DM, Dougherty DM, Mathias CW, Moeller FG, Hicks LR (2002) Comparisons of women with high and low trait impulsivity using behavioral models of response-disinhibition and reward-choice. Personal Individ Differ 33:1291–1310

Martens S, Valchev N (2009) Individual differences in the attentional blink—the important role of irrelevant information. Exp Psychol 56:18–26

Martens S, Wyble B (2010) The attentional blink: past, present, and future of a blind spot in perceptual awareness. Neurosci Biobehav Rev 34:947–957

Martens S, Munneke J, Smid H, Johnson A (2006) Quick minds don't blink: electrophysiological correlates of individual differences in attentional selection. J Cogn Neurosci 18:1423–1438

Martens S, Korucuoglu O, Smid HGOM, Nieuwenstein MR (2010) Quick minds slowed down: effects of rotation and stimulus category on the attentional blink. PLoS One 5(10):e13509. Retrieved from www.plosone.org

McCarthy G, Donchin E (1981) A metric for thought: a comparison of P300 latency and reaction time. Science 211:77–80

Mobini S, Grant A, Kass AE, Yeomans MR (2007) Relationships between functional and dysfunctional impulsivity, delay discounting and cognitive distortions. Personal Individ Differ 43:1517–1528

Olivers CN, Nieuwenhuis S (2006) The beneficial effects of additional task load, positive affect, and instruction on the attentional blink. J Exp Psychol Hum Percept Perform 32:364–379

Polich J (2007) Updating P300: an integrative theory of P3a and P3b. Clin Neurophysiol 118:2128–2148

Reeve CL (2007) Functional impulsivity and speeded ability test performance. Int J Sel Assess 15:56–62

Russo PM, De Pascalis V, Varriale V, Barratt ES (2008) Impulsivity, intelligence and P300 wave: an empirical study. Int J Psychophysiol 69:112–118

Taatgen NA, Juvina I, Schipper M, Borst JP, Martens S (2009) Too much control can hurt: a threaded cognition model of the attentional blink. Cogn Psychol 59:1–29

Troche SJ, Schweizer K, Rammsayer TH (2009) The relationship between attentional blink and psychometric intelligence: a fixed-links model approach. Psychol Sci Q 51:432–448

Vigil-Colet A, Morales-Vives F, Tous J (2008) The relationship between functional and dysfunctional impulsivity and aggression across different samples. Span J Psychol 11:480–487

Vogel EK, Luck SJ, Shapiro KL (1998) Electrophysiological evidence for a postperceptual locus of suppression during the attentional blink. J Exp Psychol Hum Percept Perform 24:1656–1674

Wierda SM, van Rijn H, Taatgen NA, Martens S (2010) Distracting the mind improves performance: an ERP study. PLoS One 5:e15024. Retrieved from www.plosone.org