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Here's Looking at You, Bud: Alcohol-Related Memory Structures Predict Eye Movements for Social Drinkers With Low Executive Control

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Abstract

This research investigated the role of individual differences for the control of attention in the early stages of self-regulation. Theories on the development of addiction posit that repeated substance use alters memory structures referring to the substance through classical conditioning processes, leading to the attention-grabbing properties of the substance. The authors predicted that such memory structures influence attentional processes toward the substance, but only in individuals with low executive control. One executive function that is closely related to attention control is working memory capacity. Using eye-tracking methodology, the authors found individual differences in an alcohol single category implicit association test to predict indicators of attention allocation such as initial orienting and attention maintenance for social drinkers low but not high in working memory capacity. This effect primarily resulted from the controlled attention component as opposed to the short-term memory component of working memory capacity. Implications and directions for further research are discussed.

Keywords

attention, self-regulation, implicit measures, working memory capacity, alcohol

Consider a prolonged glance at a tantalizingly dressed person or the close visual investigation of glistening drops gliding down the glass of a fresh draft beer. Failures to control attention can be the starting point for unfortunate behavioral episodes such as infidelity or substance abuse (Baumeister, Heatherton, & Tice, 1994). Successful attention control, by contrast, is associated with short- and long-term self-regulatory success in life (Rodriguez, Mischel, & Shoda, 1989; Shoda, Mischel, & Peake, 1990).

Stimuli that enjoy such a high priority in cognitive processing as those described in the introductory paragraph can lead to an attentional bias (AB). That is, they preferentially capture an individual's attention compared to other environmental stimuli, demanding self-regulatory efforts if the bias works in contrast to self-regulatory goals. This study addresses the question of how individual differences influence the emergence of AB toward alcohol. Specifically, we suggest that individual differences in alcohol-related memory structures and executive control dynamically interact to give rise to alcohol-related AB in social drinkers.

AB Toward Alcohol and Drugs

Research on AB and substance use (for reviews, see Field & Cox, 2008; Field, Munafò, & Franken, 2009) is informative for understanding the antecedent processes of AB. Several theories posit that AB toward drugs develops through classical conditioning processes (Franken, 2003; Robinson & Berridge, 1993). Through repeated use, substance-related memory structures change in a way that substance-related cues increasingly acquire incentive-motivational properties and become attractive. According to these views, increases in AB lead to stronger cravings for the drug, which in turn are thought to further enhance AB and thus increase the likelihood of consuming the drug. Thus, the control of attention poses an early-stage self-regulatory challenge in the form of ignoring salient stimuli to the extent that they are task irrelevant and instead voluntarily directing attention in the service of goal fulfillment. In line with this view, heavy substance users have often but not consistently shown stronger ABs than light users (Field & Cox, 2008). For example, heavy drinkers showed stronger interference effects

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in a modified Stroop task using alcohol-related words (Cox, Fadardi, & Pothos, 2006), but only when the participants were simultaneously exposed to alcohol-related posters in the room, and not when the posters were music-related (Cox, Yeates, & Regan, 1999).

Neglect of Individual Differences

Which psychological processes determine the strength of AB for a given individual? Knowledge about AB in addictive behaviors has been growing rapidly in recent years. This research has been dominated by approaches comparing different groups (e.g., light vs. heavy drinkers; Cox et al., 1999) or the effects of experimental manipulations on AB (e.g., administration of an alcoholic vs. nonalcoholic drink; Schoenmakers, Wiers, & Field, 2008). Individual differences that could explain the emergence and strength of AB on an individual-based as compared to a group-based analysis have been underrepresented. One notable exception is a study reporting a positive correlation between AB and impulsive decision making in a sample of light and heavy drinkers, presumably because highly impulsive individuals are less likely to withstand the attention-grabbing properties of alcohol-related cues (Field, Christiansen, Cole, & Goudie, 2007).

More generally, the assumption that AB develops through the transformation of substance-related memory structures via classical conditioning processes suggests that individual differences in such memory structures may play a key role in the determination of AB. The more these structures signal attractiveness and incentive-motivational properties of the substance, the greater the role they may play in the bottom-up allocation of attention. This should hold, however, only as long as there is no top-down control that would override the initiated attentional processes. For individuals with high executive control, even memory structures signaling high attractiveness and strong incentive-motivational properties should be comparatively unsuccessful in transforming into behavior.

Executive functions that seem essential for an efficient regulation of activated memory structures are attention control and response inhibition. These abilities are like "two sides of the same coin" (E. K. Miller & Cohen, 2001, p. 186) because the allocation of attention favoring certain information implies inhibiting other information. A primary executive control component that is closely related to both attention control and response inhibition is working memory capacity (WMC; Barrett, Tugade, & Engle, 2004; Knudsen, 2007). WMC has been repeatedly shown to play a crucial role for the allocation of attentional resources and the inhibition of visual and motor responses (e.g., Fukuda & Vogel, 2009; Sobel, Gerrie, Poole, & Kane, 2007 ; for a recent overview, see Kane, Conway, Hambrick, & Engle, 2007). For instance, in an antisaccade task, high WMC individuals were more successful in generating volitional eye movements and suppressing reflexive saccades as compared to low WMC individuals (Unsworth, Schrock, & Engle, 2004).

WMC is thought to be closely related to short-term memory (STM). In particular, several theories suggest that working memory is composed of STM plus a controlled attention component that is also responsible for the ability to inhibit prepotent responses (e.g., Baddeley & Hitch, 1974; Cowan, 1995; Engle, Tuholski, Laughlin, & Conway, 1999; Norman & Shallice, 1986). Hence, applied to present purposes, it is primarily this controlled attention component of WMC that should play the crucial role in the emergence and control of AB.

The Present Research

We set out to predict AB toward alcohol cues in a sample of social drinkers. To that end, we measured eye movements while participants viewed alcohol-related and soft-drink-related pictures in a picture-viewing task. This task allowed us to extract several different indicators of AB such as the *initial orienting* of attention and *attention maintenance* on substance-related cues (Field & Cox, 2008). As predictors, we first assessed individual differences in alcohol-related memory structures using a single category implicit association test (SC-IAT; Bluemke & Friese, 2008; Karpinski & Steinman, 2006), a task from the class of implicit measures (Fazio & Olson, 2003; Wittenbrink & Schwarz, 2007). Although there is debate about what exactly implicit measures measure (De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009; Fiedler, Messner, & Bluemke, 2006; Klauer, Voss, Schmitz, Teige-Mocigemba, 2007), many researchers believe that they tap into memory structures that form in consequence of conditioning experiences (Gawronski & Bodenhausen, 2006; Greenwald et al., 2002; Strack & Deutsch, 2004). They may thus provide a proxy for the memory structures that are believed to transfer into behavior under conditions of low executive top-down control (Hofmann, Friese, & Strack, 2009).

Second, we assessed executive control using a complex span WMC task (Conway et al., 2005). To separately investigate the contributions of the STM component and the controlled attention component of WMC, we also used a simple span STM task. Note that there are neither pure WMC tasks nor pure STM tasks. Both task families reflect similar cognitive operations, but to different degrees. WMC tasks are believed to assess those cognitive skills to a greater extent that are responsible for top-down control of attention and inhibition (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle et al., 1999).

Previous work has shown a moderating role of executive control on the influence of implicit measurement outcomes on social behaviors, such as self-reported alcohol consumption, eating, and anger expression (Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Thush et al., 2008; for a review, see Friese, Hofmann, & Schmitt, 2008). However, possible effects on attention allocation processes remain unknown. We expected the SC-IAT scores to predict AB toward alcohol cues, but only for individuals with low executive control.

Method

Participants

In all, 60 males, mostly students of various disciplines, participated for the equivalent of $17. We excluded 11 participants because of missing eye movement data following calibration difficulties of the eye tracker (6), failure to follow instructions (4; e.g., unauthorized abort of the computer program), and more than 25% errors in the SC-IAT (1). The mean age of the final sample was 25.20 years ($SD = 7.22$, range = 18–49).

Procedure

First, participants completed the SC-IAT and measures of WMC and STM. Next, the picture-viewing task followed after a calibration phase of the eye tracker. Finally, participants answered some control questions including demographics and a screening for alcohol-related problems. Participants were alone in the room except for the initial reception, the calibration of the eye tracker, and the debriefing. However, they could communicate with the experimenter at any time on request via intercom.

Measures and Materials

SC-IAT. Category labels were *pleasant, unpleasant*, and *alcohol*. Evaluative categories were represented by 5 stimuli and the alcohol category by 10. Evaluative stimuli were positive and negative words and pictures taken from the International Affective Picture System (Lang, Bradley, & Cuthbert, 2005). Alcohol stimuli were words and pictures of various alcoholic beverages. In a training block of 20 trials, participants sorted pleasant and unpleasant stimuli on two different response keys. In the first (second) critical block, *alcohol* and *pleasant* (*unpleasant*) shared one response key. Each critical block contained 70 trials in a predetermined random order. The proportion of left and right key responses was 3:4 in the first combined block and 4:3 in the second combined block. Block order was held constant across participants because the primary interest of this study was on individual differences and not on mean SC-IAT effects (Egloff & Schmukle, 2002). SC-IAT scores were calculated using the D600 algorithm (Greenwald, Nosek, & Banaji, 2003), such that more positive values indicated a more positive reaction to alcohol. The mean error rate was 6.01% ($SD = 4.13$). Internal consistency was calculated based on four mutually exclusive subsets of trials ($\alpha = .73$).

WMC. A complex span task was used to assess WMC (Oberauer, Süß, Schulze, Wilhelm, & Wittmann, 2000). Sequences of simple equations were presented for 3 s each. Equations consisted of one addition or subtraction, which was either correct or incorrect (e.g., "3 + 5 = 8"). After each sequence, participants were prompted to enter the suggested one-digit result of the equations in the correct order. As a secondary task, participants judged each equation as either "true" or "false" by pressing the appropriate key. Of these responses, 89% were correct, indicating that participants were seriously engaged in the secondary task while memorizing the results of the equations. After one practice trial, sequence length increased gradually from three to eight, with three sequences per length. The sum of correctly reported sequences served as an indicator of WMC. The Spearman–Brown corrected split-half reliability was $r = .75$.

STM. STM was assessed with a simple span task (Engle et al., 1999). Sequences of one- or two-syllable words were presented for 1 s each. After a sequence of words, participants were prompted to enter the words in the correct order. Thus, participants could keep their attention on the main task without having to shift attention back and forth between two competing and reciprocally interfering tasks. After one practice trial, sequence length gradually increased from three to eight, with three sequences per length. The sum of correctly reported sequences served as an indicator of STM. The Spearman–Brown corrected split-half reliability was $r = .67$.

Picture-viewing task. Participants were asked to look at various pairs of pictures until they felt comfortable enough to answer a couple of questions about each pair and to press the space bar to move on to the next screen. Pairs consisted of one alcohol-related and one soft-drink-related picture (e.g., a bottle of vodka and a bottle of mineral water). They were matched in size, colorfulness, and content (e.g., emblems, bottles, glasses). The position (left or right) of alcohol and soft drink pictures was counterbalanced. Each of the 10 pairs (1 practice trial, 9 test trials) was followed by two questions that served to give participants a reason why they should look at the pictures (e.g., "Heineken is the major seller of beer worldwide"; 7-point scale ranging from *definitely wrong* to *definitely right*). Responses to these questions were not analyzed. We excluded one pair of pictures because of very low corrected item–total correlations, which could be due to the fact that the soft drink picture depicted a fruit juice from a brand that is not sold in Switzerland and may therefore have elicited unusual orientation reactions.

Eye movements. Participants' eye movements during the picture-viewing task were recorded and analyzed with a Tobii 1750 eye tracker using Tobii Studio 1.5 software. The direction of gaze was measured every 20 ms. Eye movements that were stable within 30 pixels for at least 100 ms were classified as fixation. We analyzed eye movements on the alcohol-related and the soft-drink-related pictures, which were defined as separate areas of interest. As dependent measures, we used the (a) time to first fixation of the alcohol picture (Spearman–Brown corrected odd–even split-half reliability $r = .39$), (b) first fixation length ($r = .10$), (c) average fixation length across all test trials ($r = .53$), and (d) total dwell time on alcohol pictures ($r = .57$). To control for general differences in attention allocation between participants, each dependent variable was calculated relative to the respective value for the soft drink picture (reversed for time to first fixation). Thus, our dependent variables were composed of direct measures of initial orienting (time to first fixation) and attention maintenance (total dwell time), with length of first fixation and average fixation length ranging in between.

Table 1. Means, Standard Deviations, and Zero-Order Correlations Among Central Variables

	1	2	3	4	5	6	7
1. SC-IAT	—	–.18	–.12	–.26	–.04	.17	.02
2. Working memory capacity		—	.47**	.02	–.28	–.27	.16
3. Short-term memory			—	–.05	–.20	–.27	.23
4. Time to first fixation				—	–.13	–.12	.00
5. First fixation length					—	.58***	–.08
6. Average fixation length						—	.19
7. Total dwell time							—
M	0.05	9.61	7.24	−146 ms	140 ms	71 ms	281 ms
SD	0.37	3.12	1.84	318 ms	143 ms	85 ms	533 ms

Note: $N = 49$. SC-IAT = single category implicit association test. Time to first fixation was calculated for soft-drink-related pictures relative to alcohol-related pictures. First fixation length, average fixation length, and total dwell time were calculated for alcohol-related pictures relative to soft-drink-related pictures.
** $p < .01$.
*** $p < .001$.

Alcohol-related problems. The Alcohol Use Disorders Identification Test (AUDIT; Saunders, Aasland, Babor, de la Fuente, & Grant, 1993) served as a check for alcohol-related problems. The mean AUDIT score was 7.76 ($SD = 5.32$, $\alpha = .78$), indicating that the sample consisted of social drinkers (Fleming, Barry, & MacDonald, 1991).

Results

Means, standard deviations, and correlations of the central variables are depicted in Table 1. Replicating previous research, WMC and STM were reliably correlated (Conway et al., 2002; Engle et al., 1999). Correlations between the dependent variables were mostly low and nonsignificant. This suggests that these indices reflect different constructs (i.e., initial orienting and attention maintenance). The only exception was a significant correlation between first and average fixation length.[1] These correlations should, however, be interpreted in the context of the multiple regression analyses reported below. To arrive at the correct beta weights, we *z*-standardized all variables (Aiken & West, 1991). Results of the multiple regression analyses with SC-IAT scores, WMC, and their interaction as predictors are depicted in Table 2. The interactions between SC-IAT scores and WMC were significant for all dependent variables, as predicted. Figure 1 reveals that in each case SC-IAT scores positively predicted the criterion for individuals low in WMC, whereas there was no or a slightly negative relationship for individuals high in WMC.[2]

Follow-up analyses revealed that for low WMC individuals the SC-IAT positively predicted average fixation length ($\beta = .65$, $t = 2.53$, $p = .015$) and total dwell time ($\beta = .57$, $t = 2.15$, $p = .037$). It was less strongly related to first fixation length ($\beta = .38$, $t = 1.47$, $p = .149$) and time to first fixation ($\beta = .24$, $t = 1.17$, $p = .358$). By contrast, for high WMC individuals SC-IAT scores were unreliably associated with first fixation length ($\beta = –.30$, $t = –1.78$, $p = .082$), average fixation length ($\beta = –.10$, $t = –0.62$, $p = .541$), and total dwell time ($\beta = –.18$, $t = –1.03$, $p = .307$). The only exception was time to first fixation, which was negatively predicted by the SC-IAT ($\beta = –.49$, $t = –2.90$, $p = .006$).

The negative simple slope for high WMC individuals in the case of time to first fixation was not predicted but does not come as a complete surprise either. In addition to the three simple slopes for high WMC individuals for the other three dependent variables in the present study, similar results emerged in a number of studies using IAT-type measures and WMC to predict behavior (Hofmann, Friese, & Roefs, 2009; Hofmann et al., 2008; Thush et al., 2008). Although none of the respective simple slopes was significantly negative, these results suggests that high WMC individuals tend to overregulate the impact of their memory structures such that they act in a way that contrasts the implications of their memory structures.

An investigation of the main effects revealed that WMC was negatively associated with first fixation length and average fixation length but not time to first fixation and total dwell time. This suggests that high WMC individuals looked equally fast and equally long at alcohol cues (relative to soft drink cues) compared to low WMC individuals. Different from low WMC individuals, however, high WMC individuals' SC-IAT scores were largely unrelated to attention deployment. This suggests that high WMC individuals' attention was not grabbed to the same extent by the largely automatic, bottom-up processing of alcohol-related cues (Gawronski & Bodenhausen, 2006). When controlling for AUDIT scores, all interactions remained significant.

Next, to demonstrate that the controlled attention component of WMC works as the key moderator in these analyses, we ran multiple aggression analyses also including the STM measure and its interaction with the SC-IAT score. Results confirmed the analyses reported above: For three out of the four dependent variables, the interaction between WMC and the SC-IAT score remained at least marginally significant with time to first fixation being the only exception. The STM × SC-IAT interaction was significant in none of these cases. This suggests that it was primarily the controlled attention component of WMC that drove the interactions in the first set of analyses.

Discussion

Self-regulation describes a plurality of different strategies to control prepotent responses such as emotions, thoughts, and

Table 2. Results of the Multiple Regression Analyses for All Four Dependent Variables

	Main analyses			Main analyses controlling for STM and its interaction with the SC-IAT		
	β	*t*	*p*	β	*t*	*p*
Time to first fixation						
SC-IAT	–.12	–0.80	.425	–.11	–0.67	.506
WMC	–.07	–0.52	.603	–.03	–0.22	.830
SC-IAT × WMC	–.36*	–2.31	.026	–.28	–1.47	.149
STM				–.06	–0.37	.714
SC-IAT × STM				–.12	–0.76	.451
First fixation length						
SC-IAT	.04	0.27	.786	.03	0.18	.862
WMC	–.33*	–2.39	.021	–.30†	–1.85	.072
SC-IAT × WMC	–.34*	–2.16	.036	–.37†	–1.93	.061
STM				–.09	–0.56	.576
SC-IAT × STM				.05	0.32	.749
Average fixation length						
SC-IAT	.27†	1.82	.075	.27†	1.77	.083
WMC	–.30*	–2.15	.037	–.22	–1.41	.165
SC-IAT × WMC	–.37*	–2.42	.020	–.33†	–1.78	.083
STM				–.15	–0.95	.347
SC-IAT × STM				–.05	–0.33	.740
Total dwell time						
SC-IAT	.20	1.27	.210	.21	1.31	.199
WMC	.12	0.82	.415	.01	0.07	.943
SC-IAT × WMC	–.37*	–2.33	.024	–.40*	–2.09	.042
STM				.22	1.38	.175
SC-IAT × STM				.02	0.15	.881

Note: $N = 49$. STM = short-term memory; SC-IAT = single category implicit association test; WMC = working memory capacity.
† $p < .10$. * $p < .05$.

impulses at various stages of behavior determination. The control of attention is a central component of this plurality at the early stages of self-regulation (Baumeister et al., 1994; Rodriguez et al., 1989). Examining attention allocation processes toward alcohol, the present study is the first to investigate the role of two antagonistic forces in the deployment of attention, memory structures as assessed with an SC-IAT and executive control, or more specifically attention control. The assessed memory structures are thought to develop as a result of classical conditioning and to underlie the attention-grabbing properties of substance cues (Franken, 2003; Robinson & Berridge, 1993). We expected top-down executive control to be capable of overriding the attentional processes triggered by substance-related memory structures and of directing attention toward alternative stimuli. For the first time, the dynamic interplay of these individual differences and their influence on attention allocation could be traced using eye-tracking methodology. Specifically, more positive SC-IAT scores with alcohol were associated with shorter times to first fixation, longer durations of first and average fixations, and longer total dwell times on alcohol cues as compared to soft drink cues in low WMC individuals. By contrast, high WMC individuals successfully counteracted the influence of substance-related memory structures, irrespective of the SC-IAT scores' strength, indicating successful self-regulation in the early stages of attention orientation and maintenance.

The present findings corroborate recent neuroscientific models that stress the central role of WMC for attention allocation processes (Kane & Engle, 2002; Knudsen, 2007). WMC tasks consistently activate areas of the prefrontal cortex that are engaged in top-down executive control, such as attention control and response inhibition (Curtis & D'Esposito, 2003). In particular, these models stress the ability of high WMC individuals to direct attention in service of optimal goal fulfillment by resisting attentional capture of salient stimuli in the environment (Fukuda & Vogel, 2009). High WMC allows individuals to voluntarily direct eye movements toward an object and to use top-down control of neural circuits representing different sensory inputs that compete for access to further working memory processing by enhancing neural activity in areas that serve the current task goal (B. T. Miller & D'Esposito, 2005).

The current results are informative for several fields of psychological research. First, they contribute to the body of research investigating the role of attention deployment in self-regulation in that they specify individual differences affecting attention control success. More generally, the study points to possible new avenues in social psychological research, where, to our knowledge, implicit measures have never been used to predict eye movements. The present approach could easily be extended to and allow for new insights in research on stereotyping, social interactions, and product perception in consumer research. Pertaining to general

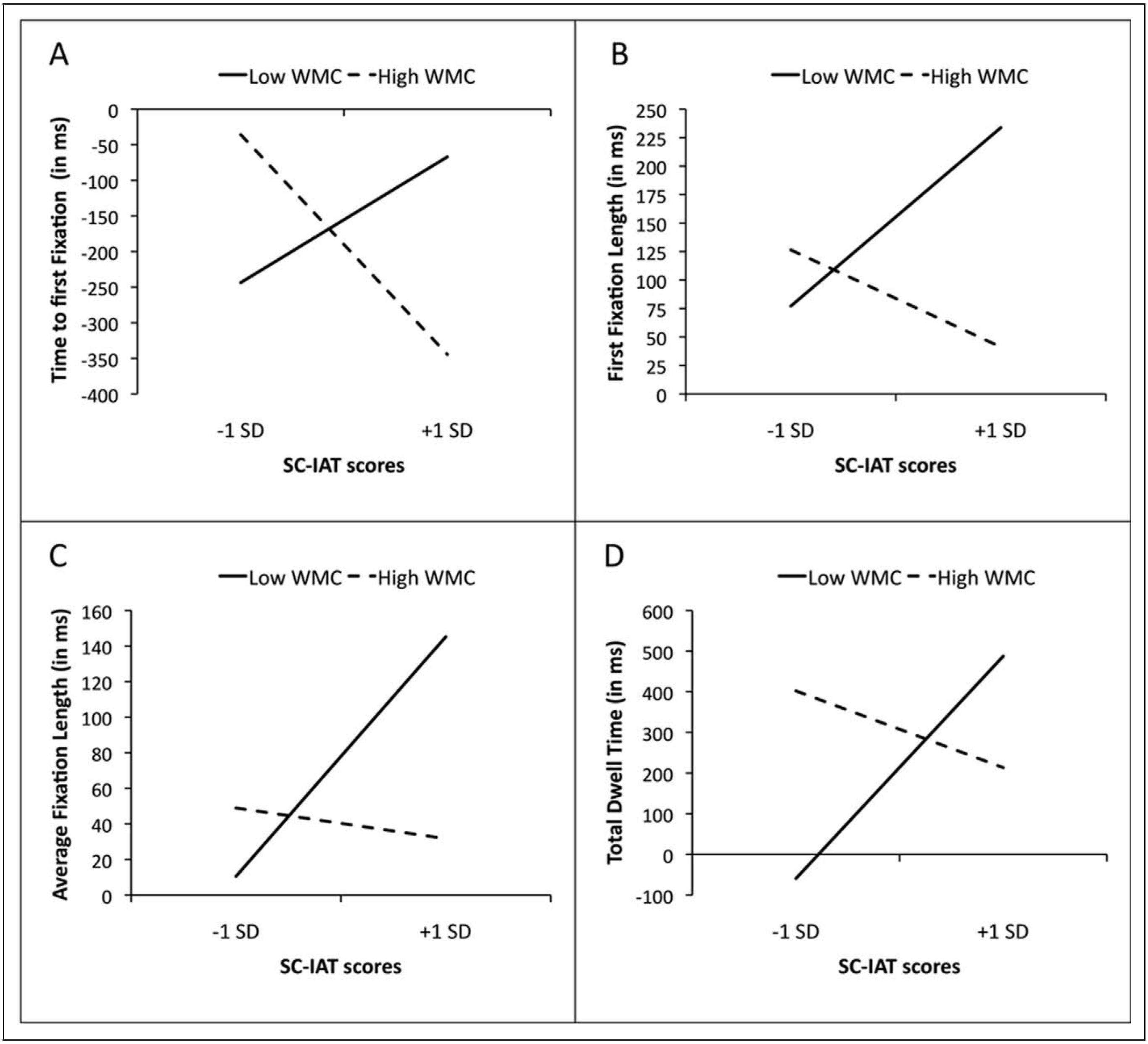

Figure 1. Influence of single category implicit association test (SC-IAT) scores on (a) time to first fixation of soft drink cues relative to alcohol cues, (b) first fixation length, (c) average fixation length, and (d) total dwell time for alcohol cues relative to soft drink cues as a function of working memory capacity (WMC; estimated slopes based on values of one standard deviation below and above the means of SC-IAT scores and WMC).

psychology, the findings are elucidating in that they specify a particular condition under which WMC helps to control visual attention in addition to inhibiting prepotent responses (i.e., when strong substance-related memory structures trigger attention allocation processes). Finally, they corroborate recent claims in the clinical literature on substance use to introduce individual differences such as executive control to research on AB (Field & Cox, 2008). They extend these claims by demonstrating the role of substance-related memory structures and their dynamic interplay with executive control.

One may wonder what motivates social drinkers with good executive functioning to control their attention toward alcohol. Because this is the first study investigating the role of executive control for AB, we can only speculate about possible reasons. First, it may be warranted to assume restraint concerning alcohol to a certain degree in our sample. After all, participants were social drinkers, indicating that they had restrained themselves in the past as compared to many other individuals drinking considerably more. This restraint may also affect attention deployment toward alcohol. This seems plausible in light of the fact that in many societies individuals learn in early childhood that the handling and consumption of alcohol are potentially dangerous and need special awareness. Over the years, this awareness may become deeply ingrained and result in attempts to strategically control attention in the service of self-regulation. Being a social drinker at a certain point in time does not free oneself from continuing to control prepotent responses including substance-related memory structures that—in the absence of executive control—may guide attention counter self-regulatory goals.

Limitations and Future Research

Several limitations of the present study have to be acknowledged. First, future research should replicate the present findings with larger samples including both sexes. Although the sample size of this study was relatively high compared to other studies on AB using eye movement data (Field & Cox, 2008), it was small for the detection of individual differences effects. This notwithstanding, the results proved largely robust against controlling for univariate and bivariate outliers.

Second, future studies should investigate the relation among substance-related memory structures, AB, and actual drinking behavior. Contemporary theories posit that AB plays a causal role in triggering substance-seeking behavior and ultimately substance use (e.g., Franken, 2003; Robinson & Berridge, 1993; Tiffany, 1990). Applied to the present approach, this view would posit that substance-related memory structures should predict alcohol consumption for individuals low in executive control, and this relationship should be mediated by AB. Ideally, this pattern would hold when controlling for parallel explicit measures to make sure that the effect is indeed driven by substance-related memory structures instead of propositional processes that may unintentionally have been captured by the implicit measure. To conclusively test this model, several predictions need to be explored: First, although all reviewed theories predict that substance-related memory structures formed through classical conditioning processes influence AB, this causal relationship should be established by means of experimental manipulations of memory structures (e.g., De Houwer, Thomas, & Baeyens, 2001; Hofmann, De Houwer, Perugini, Baeyens, & Crombez, in press) or longitudinal data. Second, regarding the basic effect of the proposed mediational pattern, recent research indeed found memory structures to predict alcohol consumption for individuals with low executive control (Friese & Hofmann, 2009; Friese, Hofmann, & Wänke, 2008; Thush et al., 2008). Third, the postulated causal role of AB for drinking behavior needs to be demonstrated. In some studies, researchers manipulated AB toward alcohol and investigated the effect of this manipulation on subsequent drinking behavior. Results of these studies were inconsistent insofar as the manipulation of AB sometimes affected subsequent drinking behavior and sometimes not (Field & Eastwood, 2005 ; Field et al., 2007). For reliable correlations to appear between AB and drinking behavior, the focus of investigation should switch from light to heavy drinkers as such correlations are difficult to find in samples of light drinkers because of restricted range problems (Field & Cox, 2008).

Third, reliabilities of the dependent measures were low, which may at least partly be because of the small number of trials and the short time durations on which they were based. Other measures of AB for substances such as the visual probe task (MacLeod, Mathews, & Tata, 1986) use more trials that appear repeatedly. Whether or not eye movement data based on such tasks exhibit higher reliabilities is difficult to judge because we were unable to locate any such studies reporting the respective information. What strengthens the confidence in the present findings is that we obtained similar results for several largely unrelated dependent variables. Nevertheless, low reliability of measures and small sample sizes generally represent a challenge for the analysis of individual differences.

Last, the effects should be generalized to other drugs, such as nicotine and cannabis, and other measures of memory structures (Fazio & Olson, 2003; Wittenbrink & Schwarz, 2007), executive control (e.g., Conway et al., 2005; Stroop, 1935), and picture viewing, such as the visual dot-probe task (MacLeod et al., 1986). If the effects generalize, they may open up new avenues for intervention and research on AB, for example, by trying to change the relevant memory structures (Olson & Fazio, 2001) or by improving WMC (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008).

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Notes

1. Recent research revealed that individuals high in working memory capacity (WMC) tend to have smaller absolute implicit association test (IAT) scores, presumably because they are better able to determine the task-appropriate, correct response, irrespective of automatically activated response tendencies (Klauer, Schmitz, Teige-Mocigemba, & Voss, in press). In contrast to these findings, in the present study high WMC individuals exhibited greater absolute single category implicit association test scores ($r = .31$, $p = .030$).
2. Extensive univariate (deviation of more than 3 standard deviations from the respective mean, boxplot) and bivariate (Mahalanobis distance, studentized t, and Cook's D) outlier analyses revealed between one and four outliers for each dependent variable except time to first fixation. For time to first fixation, there were nine univariate outliers according to the boxplot criterion, only one of which deviated more than 3 standard deviations from the mean.

Following Tabachnick and Fidell (2001), we did not treat these values as illegitimate because they amounted to more than 5% of the sample and were not clearly detached from the rest of the distribution. When removing univariate and bivariate outliers (including the participant deviating more than 3 standard deviations from the mean of time to first fixation), three of the four interactions remain significant, with average fixation length being the only exception.

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