ALCOHOL-FACILITATED DISINHIBITION OF BEHAVIOR: THE ROLE OF WORKING MEMORY LOAD

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INTRODUCTION

The relationship between alcohol intoxication and elevated rates of disinhibited behavior (e.g., aggression, sexual activity, and general risk taking) is well established. In this connection, it has been suggested that alcohol intoxication facilitates the initiation of impulsive behavior, or persistence of a behavior pattern once it is initiated. However, evidence indicates that intoxication does not invariably or even reliably result in disinhibition or perseveration either across individuals or within the same individual over different drinking occasions. Recent efforts to explain these varied effects have focused on alcohol-induced impairment of complex cognitive processes as a possible mediator of the link between intoxication and disinhibited behavior. This conceptualization draws on the observation that alcohol produces decrements in human performance that increase as the complexity of the task and/or contextual interference increases.

The goal of the present laboratory analogue study was to examine the role of alcohol-induced impairments in working memory (including interference from competing stimuli in working memory or perseveration) as possible mechanisms underlying alcohol-facilitated disinhibition of behavior. To do so, 32 undergraduate students were randomly assigned to a Beverage Condition (Alcohol; No Alcohol) and then completed a variant of the "n-back" working memory task which involved viewing a series of individual alphabetic characters presented in rapid succession on a computer screen. In the task, participants were given specific instructions about when to respond to a "target" stimulus (with a button press) and when to inhibit a response. Variations in these instructions allowed for examination of alcohol's effects on disinhibited behavior (operationalized here as Commission Error Rates) under varying levels of cognitive complexity (i.e., Memory Load). Additionally, stimuli were organized in such a way that participants were required to actively respond to 80% of stimuli in certain trial blocks at each Memory Load, but only 20% of stimuli in other blocks. Half of participants completed 20% blocks before 80% blocks at each working memory load and half completed 80% blocks first and 20% blocks second. By manipulating the Response Frequency and the Order in which these blocks occurred, we were able to examine alcohol's perseverative effects on prepotent, active responding.

SPECIFIC AIMS

1) To determine if alcohol-induced increases in error rates are specific to Commission Errors (as compared to Omission Errors).

2) To determine if alcohol-induced increases in Commission Error rates are dependent upon working memory load.

3) To analyze alcohol's effects on perseveration of behavior at varying working memory loads:

    a) Examine Commission Error Rates *within* Frequency conditions (20% vs. 80%) at different working memory loads to determine if alcohol interferes with one's ability to temporarily suspend prepotent responding in the face of infrequent inhibitory cues and, if so, whether this effect is dependent on the cognitive complexity of the context.

    b) Examine Commission Error Rates *after* a shift in Frequency conditions (20% *before* 80%; 20% *after* 80%) at different working memory loads to determine if alcohol interferes with one's ability to inhibit responding *after* switching or shifting from periods of high frequency responding to periods requiring a low frequency of response, and, if so, whether this effect is dependent on the cognitive complexity of the context.

METHOD

Participants:

Participants were 32 undergraduate students (half male) recruited as volunteers from introductory psychology classes at Florida State University. All participants were at least 21 years of age (mean age = 22.9, std. dev. = 2.3) and reported no conditions contraindicating alcohol consumption.

Procedures

- Pre-Working Memory Task
  After completion of preliminary screening measures participants were randomly assigned to a Beverage Condition. Those assigned to the Alcohol condition consumed a 95% ethyl alcohol + juice mixture calculated to approximate a mean BAL of .075. Those in the No Alcohol Condition consumed a juice only beverage of comparable volume. Beverage consumption was paced evenly over a period of 20 minutes.

- Working Memory Task
  Ten minutes after completion of beverage consumption, participants began the working memory task. Participants completed 32 one-minute trial blocks consisting of 20 letters (trials) each. Each letter stimulus was presented for 500 ms with a 2500 ms intertrial interval. In each block 20% of stimuli matched according to the Memory Load instructions and 80% of stimuli did not match. Instructions regarding Memory Load and Frequency were varied at different points within the task such that participants completed eight blocks of four different block types:

		Memory Load	
		Light Load	Heavy Load
Frequency	20%	Respond ***only*** if the stimulus matches the ***previous*** stimulus	Respond ***only*** if the stimulus matches the stimulus ***two positions back***
	80%	Respond to ***every*** stimulus unless it matches the ***previous*** stimulus	Respond to ***every*** stimulus unless it matches the stimulus ***two positions back***

NOTE: Examples of each of the four block types created by the combination of the Memory Load and Frequency manipulations are included on the next page.

For counterbalancing purposes and to help create the between-subjects Order (of frequency blocks) manipulation, participants were randomly assigned to complete the four different block types of the working memory task in one of four different orders that represented all possible combinations of Memory Load and Frequency. Thus, half of participants completed 20% blocks before 80% blocks at each Memory Load, and half completed 80% blocks first and 20% blocks second.

Overview of Independent and Dependent Measures:

- Independent Measures
  Beverage Condition (Alcohol; No Alcohol)
  Memory Load (Light; Heavy)
  Frequency (20%; 80%)
  Order (20% *before* 80%; 20% *after* 80%)

- Dependent Measures
  Commission Error Rates
  Omission Error Rates

Data Analytic Strategy

- Specific Aims #1 and #2
  A Beverage X Memory Load mixed between-within-subjects MANOVA was conducted with Commission and Omission Error Rates serving as the dependent measures.

- Specific Aim #3a
  A Beverage X Memory X Frequency mixed between-within-subjects ANOVA was conducted with Commission Error Rates serving as the dependent measure. To ensure that perseveration due to changes *between* Frequency level (i.e., changes due to the switch from one frequency level to another) did not influence the results of this analysis designed to specifically examine *within*-Frequency perseveration, only data from participants in the 20% *before* 80% and 80% *before* 20% conditions were used. Thus, in this analysis, Frequency served as a *between-subjects* independent measures with two levels (20% *before* 80%; 80% *before* 20%).

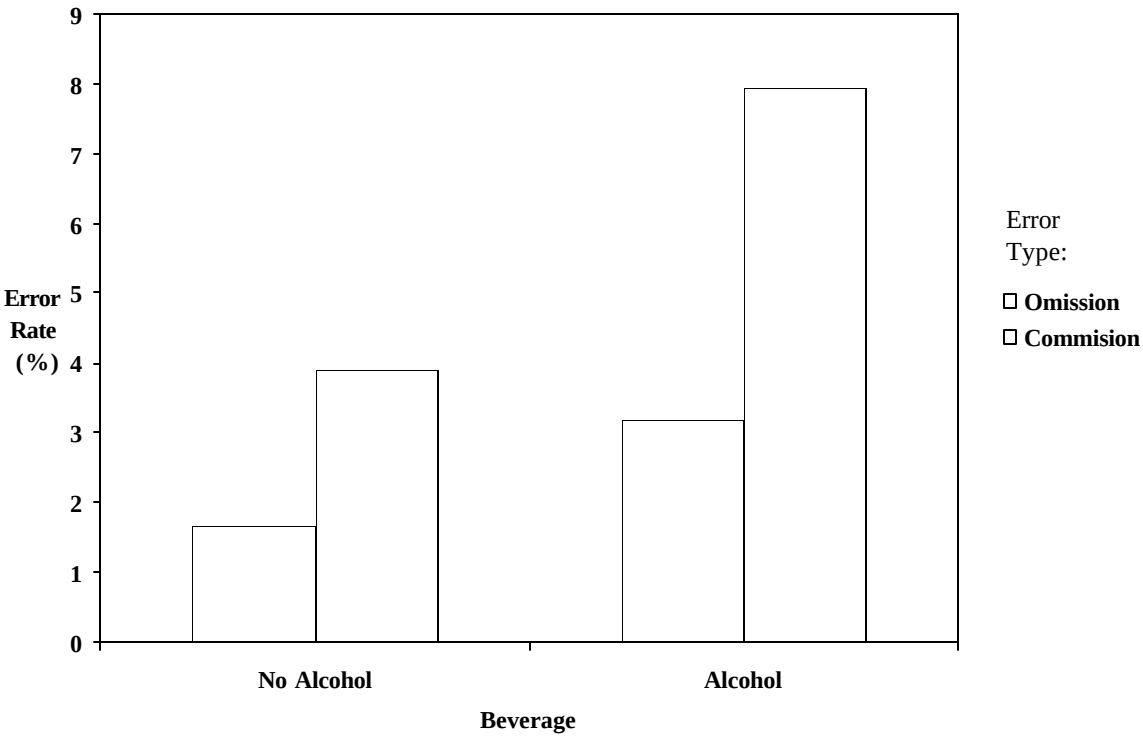
- Specific Aim #3b
  A Beverage X Memory X Order of 20% Blocks mixed between-within-subjects ANOVA was conducted with Commission Error Rates serving as the dependent measure.

RESULTS

Specific Aim #1 – To determine if alcohol-induced increases in error rates are specific to Commission Errors.

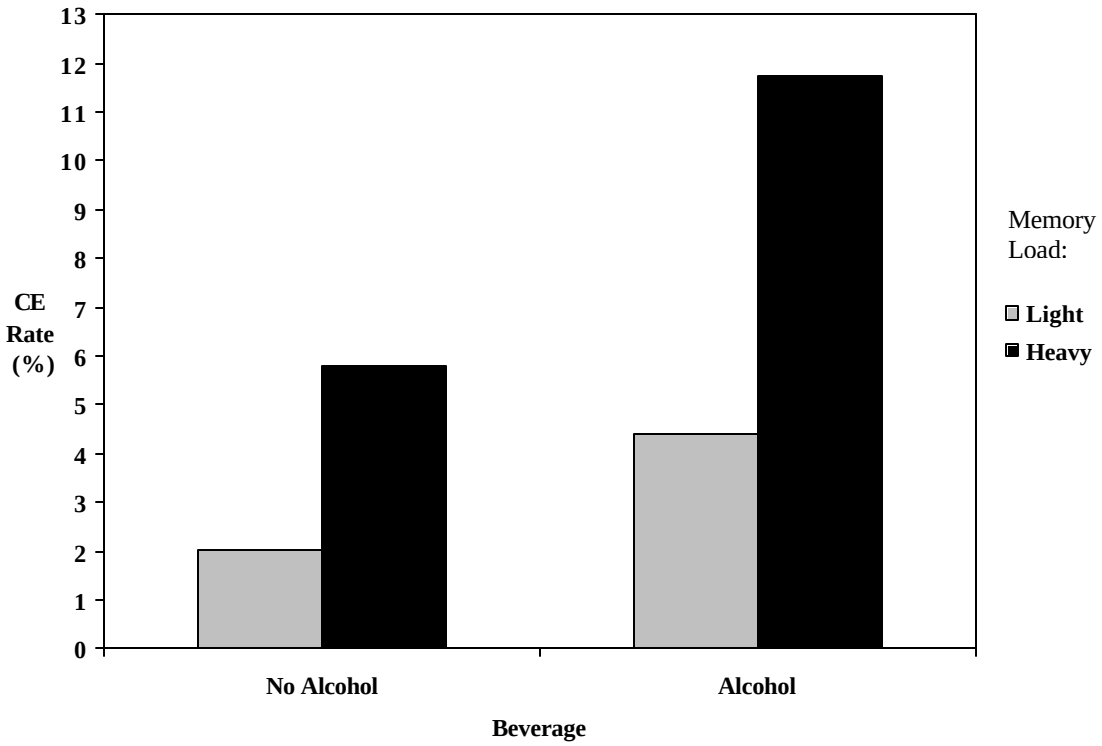
Using the Beverage X Memory Load mixed between-within-subjects MANOVA, a significant multivariate effect of Beverage $F(2, 29) = 5.31$, $p = .011$ was observed. Univariate follow-up tests indicated that:

- Overall Commission Error rates were significantly higher among intoxicated participants relative to sober, $F(1,30) = 10.315$, $p = .003$
- Overall Omission Error rates were *not* significantly different between Beverage groups, $F(1,30) = 1.93$, $p = .174$.



Specific Aim #2 – To determine if alcohol-induced increases in Commission Error rates are dependent upon working memory load.

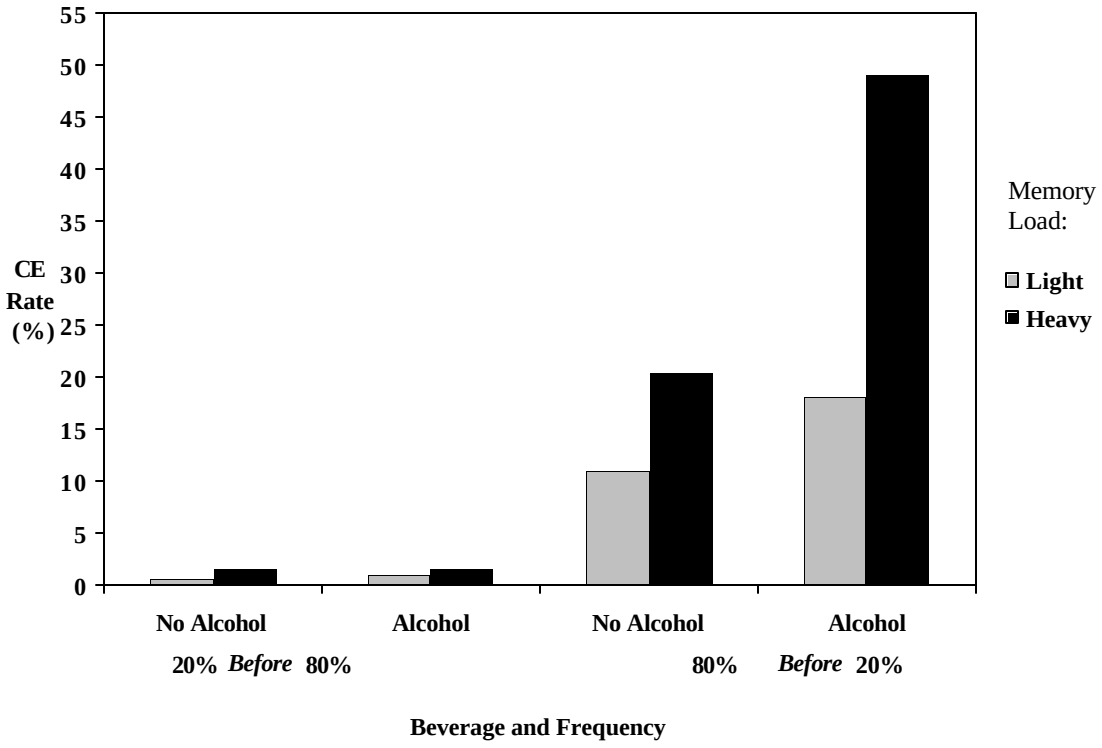
Using the Beverage X Memory Load mixed between-within-subjects MANOVA, a significant multivariate Beverage X Memory Load interaction, $F(2, 29) = 3.77$, $p = .035$ was observed. Univariate follow-up tests revealed a significant univariate Beverage X Memory Load interaction effect on Commission Error rates, $F(1, 30) = 6.43$, $p = .017$. As indicated by this interaction, the simple effect of alcohol was stronger at the Heavy Load level than at the Light Load level.



Specific Aim #3 – To analyze alcohol's effects on perseveration of behavior at varying working memory loads.

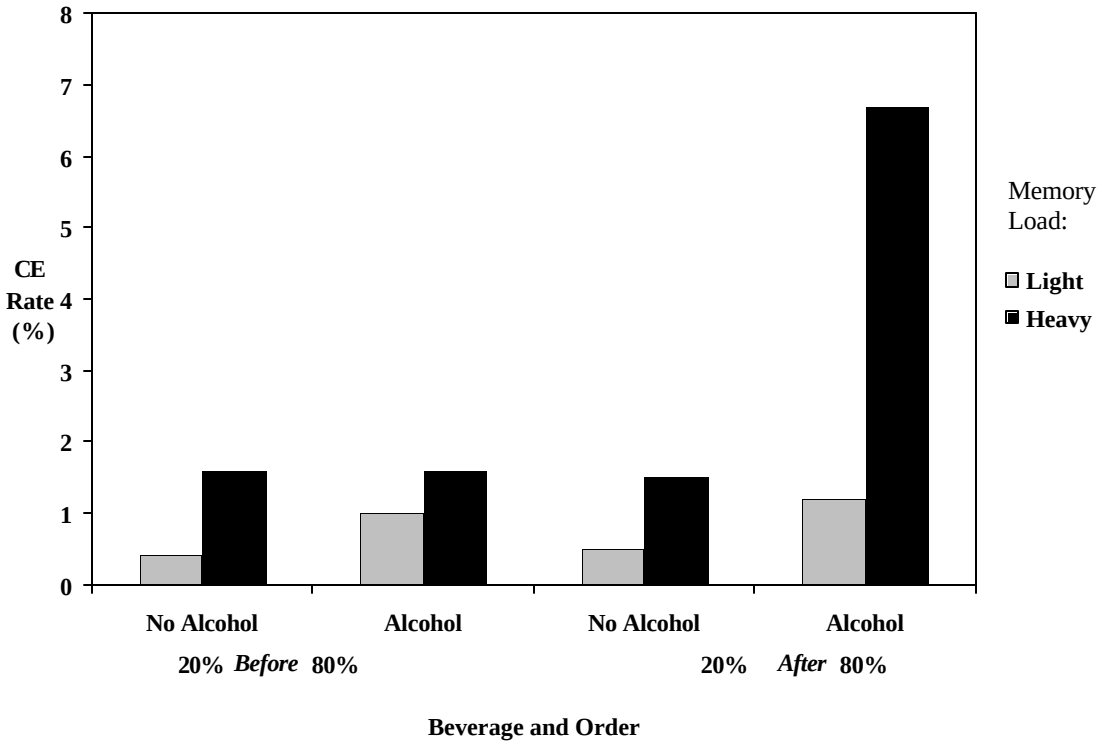
a) Examine Commission Error Rates *within* Frequency conditions (20% vs. 80%) at different working memory loads

Results from the Beverage X Memory X Frequency mixed between-within-subjects ANOVA revealed a significant Beverage X Memory X Frequency interaction, $F(1,28) = 11.039$, $p = .002$. Follow-up analyses to understand the interaction indicated that the difference between Heavy and Light load Commission Error Rates was significantly greater among intoxicated participants in 80% conditions than intoxicated participants in 20% conditions or sober participants in either Frequency condition.



b) Examine Commission Error Rates *after* a shift in Frequency condition (20% *before* 80%; 20% *after* 80%) at different working memory loads

Results from the Beverage X Memory X Order 20% Blocks mixed between-within-subjects ANOVA revealed a significant Beverage X Memory X Order interaction, $F(1,28) = 8.112$, $p = .008$. Follow-up analyses to understand the interaction indicated that the difference between Heavy and Light load Commission Error Rates in 20% blocks was significantly greater among intoxicated participants completing 20% blocks *after* 80% blocks than among intoxicated subjects completing 20% blocks *before* 80% blocks or sober subjects completing 20% blocks in either Order condition.



DISCUSSION AND CONCLUSIONS

Specific Aim #1

Consistent with the well-documented relationship between alcohol intoxication and a number of disinhibited social behaviors, intoxicated participants demonstrated a higher overall level of disinhibition (as operationalized by Commission Error rates) than their sober counterparts in the n-back working memory task. However, alcohol did not lead to significant increases in overall Omission Error rates, suggesting that intoxication is more likely to lead to errors involving an active response than errors due to a failure to act, at least at the dose tested here.

Specific Aim #2

A significant Beverage X Memory Load interaction on Commission Error rates was observed in the n-back working memory task as alcohol-induced increases in Commission Errors were more pronounced at the Heavy Load level of working memory than at the Light Load level. This finding is consistent with and lends support to the notion that alcohol-induced impairments in complex cognitive processes may underlie the relationship between alcohol intoxication and disinhibited behavior.

Specific Aim #3a

Results from the analysis of alcohol's perseverative effects *within*-Frequency condition suggested that alcohol intoxication compromises one's ability to overcome a prepotent or habitual response tendency when conditions require inhibition of responding in the face of infrequent inhibitory cues, and that this interference occurs only under cognitively complex conditions.

Specific Aim #3b

Results from the analysis of alcohol's perseverative effects *after* a shift in Frequency condition suggested that under cognitively complex conditions, alcohol also interferes with one's ability to appropriately inhibit responding following a shift from periods requiring highly frequent responding to periods requiring a low frequency of responding.

The findings from this study provide support for the plausibility of cognitive mediation of alcohol-facilitated disinhibition and suggest that alcohol's association with perseveration (difficulty withholding responses once a pattern of behavioral responding is established) may be dependent on the cognitive complexity of the task and context in which it occurs. Further, this study demonstrates the potential benefits, promise, and utility of borrowing well-researched paradigms and constructs from contemporary cognitive psychology to further our understanding of alcohol-induced phenomena, including disinhibition and perseveration of behavior.

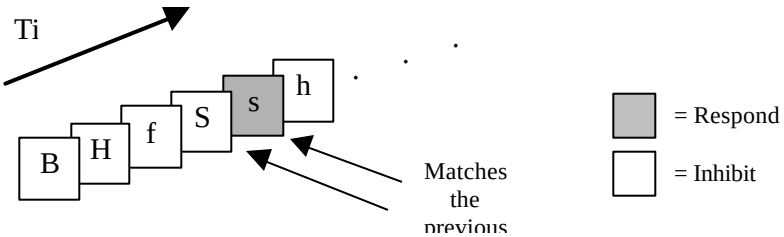
Clearly, this study represents only the initial step in the union of the literatures on cognitive psychology and alcohol-induced phenomena. In this regard, a number of potentially fruitful avenues exist for future exploration. For example, Cohen and colleagues (e.g., Botvinick, Braver, Carter, Barch, & Cohen, 1998; Braver, Barch, & Cohen, 1999; MacDonald, Cohen, Stenger, & Carter, 2000) have outlined a theory of cognitive control which may have particular relevance for understanding the mechanisms underlying alcohol-facilitated disinhibition of behavior. According to this theory, cognitive control is defined as the effortful direction, engagement, and activation of cognitive resources in the selection and processing of task-relevant information for purposes of maximizing performance and minimizing interference on tasks involving a high level of difficulty, complexity, interference, or novelty. A high degree of cognitive control is needed to (a) solve difficult, novel, or complex tasks, (b) overcome prepotent/habitual responses, and (c) correct errors. The cognitive control system is believed to involve both an *evaluative* function, responsible for monitoring information processing and determining the demand for cognitive control, and a *regulative* function, responsible for activation and implementation of control related processes. Included among the latter function is the maintenance and use of context representations (including task instructions) in working memory to guide task-appropriate behavior. Each component of this theory is amenable to direct manipulation and investigation within in the context of alcohol challenge studies. Such endeavors hold great promise for furthering our understanding of the mechanisms underlying alcohol-facilitated disinhibition of behavior.

Order	Blocks 1-8	Blocks 9-16	Blocks 17-24	Blocks 25-32
1	Light/20%	Light/80%	Heavy/20%	Heavy/80%
2	Light/80%	Light/20%	Heavy/80%	Heavy/20%
3	Heavy/20%	Heavy/80%	Light/20%	Light/80%
4	Heavy/80%	Heavy/20%	Light/80%	Light/20%

EXAMPLES OF EACH OF THE FOUR BLOCK TYPES

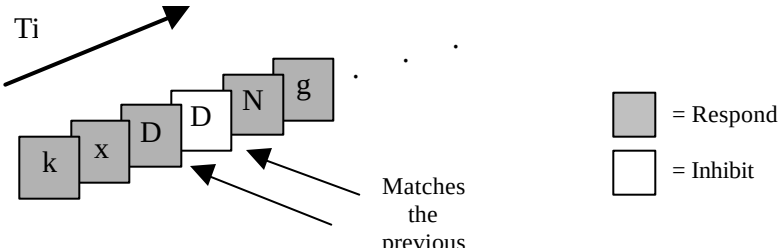
Light Load / 20%

(Respond to a letter *only* when it matches the letter 1-Back)



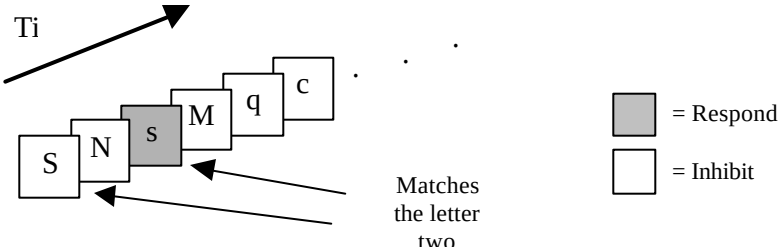
Light Load / 80%

(Respond to *every* letter *unless* it matches the letter 1-Back)



Heavy Load / 20%

(Respond to a letter *only* when it matches the letter 2-Back)



Heavy Load / 80%

(Respond to *every* letter *unless* it matches the letter 2-Back)