Effects of Response Inconsistency and Time Pressure on Automaticity Development

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Several complex tasks in the world ranging across fields such as aviation, military and healthcare require operators to develop highly skilled and automated levels of performance in response to critical stimuli in the environment. Such automatic detection processes are relevant to situations such as that of a pilot detecting the presence of an enemy aircraft among ‘friendly’ aircraft in the environment, a physician detecting the presence of tumors in x-rays, or a luggage screener detecting the presence of a hidden weapon in luggage. These complex tasks are characterized by multiple stimuli and distractors, and environmental variables such as time pressure that make the task extremely difficult to perform in the absence of a practiced skill set. Furthermore, tasks in the real world require responses be tailored to the spatial-temporal characteristics of the situation and such responses are rarely dictated by a single stimulus.

The development of automatic responding has been studied in a variety of generic target detection contexts. Of these, the classic dual-process theory of Schneider and Shiffrin (1977) postulates that automatic processing develops with extended practice when stimuli are consistently mapped to target and distractor categories over a period of extended experience. Such automatic processing is fast and parallel, and requires little attention. On the other hand, under varied-mapping conditions wherein stimuli may be targets in one instance but distractors in another, performance occurs under controlled processing, which is voluntary, serial, and requires attention. Such is often the case in complex tasks where situations and stimuli vary dramatically from one instance to another, and a one-to-one mapping of stimulus and response rarely occurs. The potential for automatic detection, therefore, is an important goal for designers of complex systems.

The present paper focuses on the factors that affect the development of automaticity in a defense related radar task. We contend that in complex environments, two types of inconsistent response mapping affect performance. Responses that are not consistently mapped to targets but are consistently mapped to the structure of the task will show little decrement in performance or response time. Conversely, responses that are neither consistently mapped to targets nor to task structure will show large decrements in performance and increases in response time. Furthermore, time pressure is likely to have a significant effect on performance efficacy in such tasks. The purpose of this study was to examine the effects of response inconsistency on performance, and to observe the manner in which time pressure interacts with response inconsistency in the development of automaticity.

Method

Participants. Eight participants completed six experimental sessions of approximately 3 hours each.

Tasks. The task was to detect and eliminate hostile enemy aircraft by selecting the appropriate weapon on a simulated radar screen. Before each trial, participants memorized a set of targets (digits or letters) representing enemy aircraft. They were then presented with 14 frames, each displaying four moving blips that represented aircraft. The task was to detect any member of the memory set that appeared and eliminate the target by pressing the appropriate key. The time between the onset of one frame and the next was 2,050 ms for the “slow” condition, and 1.050ms for the “fast” condition. Four responses were possible, each corresponding to the keys located on the four corners of the numeric keypad (1, 7, 9, 3). The numeric response keys were color coded (1 = red, 7 = blue, 9 = green, 3 = yellow). The goal was to press the key corresponding to the color of the radar axis where a target was detected.

There were four within-subject conditions:

i) *Mapped-to-stimuli*: stimuli were consistently mapped to targets; all axes on the radar grid were the same color. Participants always responded by pressing the same key.

ii) *Fully mapped*: spatial layout and color coding of the numeric keys and radar axes were redundant (e.g., the northwest axis was blue and the northwest response key (7) was also blue).

iii) *Partial-mapping*: two of the axes were given consistent spatial layouts and color coding. The other two axes were randomly assigned one of the four colors.

iv) *Random-mapping*: each axis was randomly assigned one of the four colors. Consistency between spatial layout and color coding of the responses and radar axes was random.

Results

Response time. Participants were slower to respond when frame time was slow, $F(1, 7) = 54.95$, $p < .05$, and when response mappings were inconsistent, $F(3, 21) = 20.31$, $p < .05$. Differences in response time between the frame-time conditions decreased as the participants gained experience, $F(1, 7) = 5.33$, $p < .05$. There were no differences when frame time was fast. However, when frame time was slow participants responded significantly faster to targets in the mapped-to-stimuli condition (1056 ms) than in the fully mapped (1250 ms, $p < .05$), partial-mapped (1399.19 ms, $p < .05$), or random-mapped conditions (1425.89 ms, $p < .05$). Also, response time was significantly faster in the fully mapped condition than the partial-mapped ($p < .05$) or random-mapped ($p < .05$) conditions. However, there was no difference between the partial-mapped and random-mapped conditions ($p = .61$). This supports our hypotheses that there is a significant processing cost to inconsistent responding when stimuli are consistently mapped to categories.

Accuracy. The number of hits remained relatively stable across the response-mapping conditions when frame time was slow (2,050 ms). When frame time was fast (1,050 ms), hits decreased as response mapping became inconsistent. However, the observations did not approach statistical significance. Contrary to expectations, inconsistent responding did not affect performance accuracy under consistent-attending conditions. This negates the possibility of a speed–accuracy trade off.

Conclusions

The results show that responses should be mapped to task structure to avoid processing costs. This is particularly true when tasks are complex with multiple cues, time pressure and dynamic stimuli. In contexts such as aviation, defense, and healthcare, the time taken to generate a response is often as critical as the actual accuracy of the response in itself. Therefore, the findings of this study have implications for designers in that the influence of task structure on processing requirements must be considered while designing complex systems. The size of the inconsistent-responding effect suggests that response mapping may be as important as stimulus mapping in the performance of complex tasks.