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# Consistent mapping and automatic visual search: comparing persons with and without intellectual disability

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## Abstract

*Background* Merrill *et al.* (1996) reported that persons with intellectual disability (ID) were slower at learning a visual search task to automaticity relative to persons of the same age without ID. For persons without ID, automaticity develops most rapidly under conditions in which a response is always the same for a particular stimulus. This study was designed to investigate whether persons with and without ID are differentially sensitive to the influence of consistently mapped versus inconsistently mapped stimulus responses.

*Methods* The primary manipulation was the consistency between a particular stimulus and the response to that stimulus in a visual search task. Sixteen participants with ID and 16 without ID searched displays of two, three, or four pictured objects to determine if a target was present. For half of the participants, the targets were always targets. For the other half, the targets became nontargets on 25% of the trials.

*Results* Analyses focused on changes in response times associated with set size. Because automaticity allows for parallel processing, the elimination of significant effects of set size was taken as an index of the development of automaticity. Results indicated that inconsistent mapping significantly slowed the development of automaticity for the participants without ID but not for the participants with ID.

*Discussion* Results were discussed in terms of the role of inhibition processes in the development of automatic search and detection. The effectiveness of inhibition processes was compromised by the consistency manipulation. The effect of the consistency manipulation was greater for the participants without ID because they were presumed to be using inhibition processes more effectively during practice than did the participants with ID.

**Keywords** attention, automatic processing, intellectual disability

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## Introduction

Skilled performance involves many cognitive processes, some of which require cognitive effort to be executed and others of which are executed relatively automatically (e.g. Pew 1974; Neuman 1984). It has been assumed that lower level activities must be executed without drawing from available resources to ensure resources are available to execute higher level activities of the skill (e.g. LaBerge & Samuels 1974; Logan 1979, 1985). Persons who do not execute basic operations automatically should be less able to perform the higher order skills. Merrill (1990, 1992) found differences in the degree to which persons with and without intellectual disability (ID) have automated some basic information processing operations. Hence, important differences in skilled performance between persons with and without ID may result from differences in the rate at which basic cognitive operations are automated.

Merrill *et al.* (1996) reported that persons with ID were slower at learning a visual search task to automaticity relative to persons of the same age without ID. Participants searched for the presence of a target in sets of two, three, or four pictures. Automaticity was evidenced by a decrease in the effect of search set size with practice. At the beginning of the studies, all participants exhibited a linear increase in search times as set size increased. However, as practice continued, participants eventually exhibited no effect of set size at all. At that point, participants were assumed to be performing the task automatically, because automatic processing allows participants to process information in parallel (see Fisk & Schneider 1983). The participants with ID required approximately twice as many practice trials as the participants without ID to evidence automaticity.

My current experiment was designed to investigate whether persons with and without ID are differentially sensitive to the influence of consistently versus inconsistently mapped targets during the development of automaticity. For persons without ID, automaticity develops most rapidly under consistently mapped conditions in which a response is always the same for a particular stimulus: a target is always a target and a nontarget is always a nontarget (e.g. Schneider & Shiffrin 1977; Shiffrin & Schneider 1977; Logan 1979; Schneider & Fisk 1982; Fisk & Schneider 1983, 1984). No studies have investigated the relation between consistency of mapping and automaticity for persons with ID.

There is a long history of research that indicates difficulties associated with the inhibition of irrelevant stimuli by persons with relative to persons without ID. Inhibition difficulties were reported by Zeaman & House (1963) and were prominent in their early theories. Denney (1964) and Heal & Johnson (1970) also argued for an important role for inhibition processes in explaining learning problems associated with ID (see also Luria 1963). Using a negative priming paradigm (Tipper & Cranston 1985), Cha & Merrill (1994) reported that persons with ID were less sensitive to some aspects of nontargets in tasks of visual selection than are persons without ID. In their study, each trial included a prime display followed by a probe display, and each display included a target and distractor. On some trials the distractor in the prime became a target in the probe. Adolescents without ID typically exhibit a slowing of response times (relative to a neutral condition) to targets that were distractors in the prime (Tipper 1985; Tipper & Cranston 1985). Cha and Merrill found that adolescents with ID did not exhibit this typical slowing of response times.

If these results reflect a lesser likelihood of using nontarget information on the part of adolescents with ID, then adolescents with ID may be affected less by inconsistently mapped targets during automatization than are adolescents without ID. In other words, adolescents without ID should be much slower to develop automaticity in a task when targets and nontargets are not consistently mapped, whereas adolescents with ID may not be slowed as much. In the experiment reported here, participants were tested in conditions where particular stimuli were targets 100% of the time or were targets 75% of the time and nontargets 25% of the time. We expected that participants without ID would require approximately twice as many practice trials to acquire automatic processing in the 75% condition than in the 100% condition (see Schneider & Fisk 1982). If adolescents with ID are less affected by the inconsistent mapping of targets and nontargets, then they should exhibit a smaller difference in the amount of practice necessary to achieve automaticity across consistency conditions.

## Materials and methods

### Participants

Sixteen adolescents with ID (mean Age = 18.2, SD = 0.7, mean IQ = 61.2, SD = 7.6) and 16 adolescents without ID participated (mean Age = 18.5, SD = 0.9). The participants with ID were recruited from local schools. IQ scores were based on recent administrations of the WISC-III. The participants without ID were recruited from Introductory Psychology classes at the University. Participants were paid $25. The dominant hand of all participants was the right hand.

## Stimuli and apparatus

Stimuli were presented on a Macintosh LC computer using the Superlab experimental software (Cedrus Corp.). Stimuli were displays of two, three, or four line drawings of common objects presented diagonally across the computer screen (see Fig. 1). Stimuli included four common objects from six conceptual categories: four-legged mammals, clothing, fruit, furniture, tools, and vehicles. Two categories (clothing and furniture) were alternately designated as the target category across each of several presentation blocks. In the 100% consistent condition, clothing never appeared in trials when furniture was the target and furniture never appeared when clothing was the target. In the 75% consistent condition, clothing appeared as a nontartget on 25% of the trials when furniture was the target and furniture appeared on 25% of the trials when clothing was the target. For displays of less than four items, a checkerboard pattern was presented in the last one or two positions of the array to keep displays similar in size.

Responses were made on the keyboard, with 'S' and 'L' relabelled 'no' and 'yes' to facilitate responding. 'Yes' responses were made with the right hand and 'no' responses with the left hand.

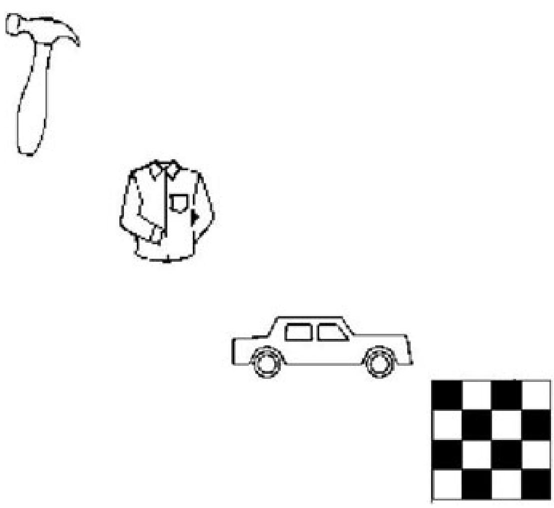

**Figure 1** Example of stimulus search displays.

## Design

Variables were participant groups (with and without ID), consistency (100% and 75%), sessions (1–5), set size (2, 3, and 4), and response type (yes and no). Sessions, set size, and response type were manipulated within participants and consistency between participants. The dependent variable was response time to determine whether the display contained a target.

## Procedure

Participants were tested in 45 min sessions on 5 consecutive days. Half of the participants in each group were randomly assigned to each consistency condition. Participants received five blocks of 90 trials with clothing as the target category and five blocks of 90 trials with furniture as the target category in each session. Targets alternated between presentation blocks. Trials included the presentation of a fixation array, followed 750 ms later by the presentation of a stimulus array. The fixation array consisted of a cross in the upper left corner of the array designating the location of the first stimulus in the display, and three dots angling diagonally to the right indicating locations of other stimuli. The stimulus array was visible until a response was made. Response times were recorded by computer to the nearest ms.

# Results

Data are reported in Table 1 (response times) and Table 2 (errors). Analysis of response times was limited to target present trials. Previous research (and logic) indicated that 'no target' trials are not informative about the development of automatic processing (Merrill *et al.* 1996). As also observed in Merrill *et al.* (1996), the participants with ID exhibited a larger effect of set size in session 1 than did the individuals without ID. However, the primary question involved the influence of consistent mapping on the development of automatic processing within groups. Therefore, I analysed the effect of consistency of mapping separately for each group and then evaluated the difference in the amount of practice required to achieve automatic processing across groups.

**Table 1** Mean response times (in ms) for participants with and without intellectual disability (ID) as a function of session, consistency of mapping, and set size. Standard deviations are reported in parentheses

| | With ID | | | | | | Without ID | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75% | | | 100% | | | 75% | | | 100% | | |
| | Set size | | | Set size | | | Set size | | | Set size | | |
| Session Consistency | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 |
| 1 | 957 | 1043 | 1177 | 941 | 1034 | 1137 | 688 | 732 | 792 | 673 | 710 | 766 |
| | (133) | (198) | (197) | (216) | (255) | (243) | (38) | (46) | (68) | (37) | (36) | (41) |
| 2 | 786 | 856 | 897 | 713 | 751 | 822 | 622 | 651 | 694 | 584 | 593 | 628 |
| | (97) | (119) | (134) | (135) | (150) | (155) | (49) | (57) | (57) | (39) | (35) | (54) |
| 3 | 755 | 809 | 877 | 698 | 714 | 774 | 606 | 650 | 684 | 578 | 590 | 593 |
| | (159) | (164) | (146) | (129) | (141) | (138) | (62) | (66) | (64) | (57) | (58) | (50) |
| 4 | 714 | 758 | 801 | 662 | 671 | 716 | 598 | 607 | 645 | 561 | 564 | 577 |
| | (96) | (91) | (92) | (106) | (120) | (124) | (45) | (53) | (60) | (54) | (47) | (51) |
| 5 | 780 | 778 | 794 | 687 | 679 | 701 | 610 | 623 | 627 | 548 | 551 | 555 |
| | (144) | (153) | (121) | (110) | (121) | (120) | (69) | (70) | (59) | (51) | (57) | (46) |

**Table 2** Mean per cent errors on 'yes' response trials for participants with and without intellectual disability (ID) as a function of session, consistency of mapping, and set size. Standard deviations are in parentheses

| | With ID | | | | | | Without ID | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75% | | | 100% | | | 75% | | | 100% | | |
| | Set size | | | Set size | | | Set size | | | Set size | | |
| Session Consistency | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 | 2 | 3 | 4 |
| 1 | 2.0 | 3.2 | 4.1 | 2.1 | 3.1 | 4.3 | 2.1 | 3.1 | 2.0 | 2.3 | 2.6 | 2.2 |
| | (1.6) | (2.2) | (2.5) | (1.3) | (1.9) | (2.3) | (1.1) | (1.9) | (1.4) | (1.1) | (1.3) | (1.0) |
| 2 | 1.7 | 2.7 | 3.2 | 1.6 | 2.2 | 3.3 | 2.7 | 3.0 | 2.8 | 3.0 | 2.4 | 2.1 |
| | (1.2) | (2.0) | (2.4) | (1.1) | (1.9) | (2.6) | (1.6) | (1.6) | (1.8) | (2.0) | (1.2) | (0.9) |
| 3 | 2.2 | 3.5 | 4.6 | 2.1 | 1.7 | 0.7 | 2.5 | 2.6 | 3.1 | 1.8 | 1.3 | 2.9 |
| | (1.8) | (2.6) | (2.7) | (1.7) | (1.3) | (0.5) | (1.2) | (1.3) | (1.7) | (0.9) | (0.7) | (1.3) |
| 4 | 4.8 | 8.6 | 10.7 | 3.0 | 2.7 | 2.9 | 3.2 | 2.2 | 2.9 | 3.1 | 2.5 | 2.0 |
| | (2.9) | (3.9) | (4.4) | (2.0) | (2.1) | (1.6) | (1.8) | (1.1) | (1.4) | (1.6) | (1.4) | (0.8) |
| 5 | 8.8 | 12.3 | 16.7 | 2.0 | 2.1 | 1.7 | 1.7 | 1.1 | 2.4 | 2.6 | 2.2 | 2.5 |
| | (4.0) | (5.1) | (6.0) | (1.5) | (1.7) | (1.1) | (0.8) | (0.5) | (1.1) | (1.3) | (1.1) | (1.1) |

## Response times

Response times for the participants with ID were analysed using a 2 (consistency) × 5 (sessions) × 3 (set size) analysis of variance, with sessions and set size treated as within participant manipulations. The analysis revealed a significant effect of session, $F_{4,56} = 30.59$, $P < 0.01$ (1048, 804, 771, 720, and 737 ms for sessions 1–5, respectively) and a significant effect of set size, $F_{2,28} = 146.10$,

$P < 0.01$ (769, 809, and 869 for set sizes 2, 3, and 4, respectively). These effects were qualified by the significant interaction of sessions and set size, $F_{8,112} = 22.12$, $P < 0.01$. Test of simple effects indicated that the effect of set size was significant for sessions 1, 2, 3, and 4, but not significant for session 5 (all significant $P$'s < 0.05). Thus, the participants with ID exhibited evidence of automaticity during session 5. The three-way interaction of consistency, sessions, and set size was not significant indicating that consistency of mapping did not influence the amount of practice needed to achieve automaticity for the participants with ID.

Response times for the participants without ID were analysed in the same manner. This analysis revealed a significant effect of consistency, $F_{1,14} = 4.74$, $P < 0.05$, with participants responding faster in the 100% consistent condition than in the 75% consistent condition (605 versus 655 ms). There was a significant effect of sessions, $F_{4,56} = 74.76$, $P < 0.01$ (727, 629, 617, 592, and 586 for sessions 1–5, respectively) and a significant effect of set size, $F_{2,28} = 181.90$, $P < 0.01$ (606, 627, and 65 ms for set size 2, 3, and 4, respectively). However, these effects were qualified by the significant interactions of consistency × set size, $F_{2,28} = 17.41$, $P < 0.01$, sessions × set size, $F_{8,112} = 17.63$, $P < 0.01$, and consistency × sessions × set size, $F_{8,112} = 2.47$, $P < 0.05$.

For the participants without ID, there was a significant interaction of sessions × set size in both consistency conditions; $F_{8,56} = 15.84$, $P < 0.01$ for the 100% consistent condition, and $F_{8,56} = 7.08$, $P < 0.01$ for the 75% consistent condition. However, the patterns of effects were different. In the 100% consistent condition, set size was significant only for sessions 1 and 2 (both $P$'s < 0.05). In the 75% consistent condition, set size was significant for sessions 1, 2, 3, and 4 (all $P$'s < 0.05), but not 5. It took approximately twice as much practice to achieve evidence of automatic processing in the 75% consistent condition than in the 100% consistent condition. This result is similar to that reported by Schneider and colleagues for college students (e.g. Fisk & Schneider 1983). Adults without ID typically exhibit slower development of automaticity as the consistency of target mapping is decreased.

## Errors

Total errors (misses and false alarms) for the participants with ID were analysed using a 2 (consistency) × 5 (sessions) × 3 (set size) analysis of variance, treating sessions and set size as within participant variables. There was a significant effect of consistency, $F_{1,14} = 8.82$, $P < 0.01$ (more errors in the 75% than the 100% condition), and a significant effect of sessions, $F_{4,56} = 97.44$, $P < 0.01$ (more errors in the later than in the early sessions). However, these effects were qualified by the interaction of consistency × session, $F_{4,56} = 23.21$, $P < 0.01$. Tests of simple effects revealed that errors increased in the 75% condition as sessions increased, with maximum error rates observed in session 5. There was no difference in error rates across sessions in the 100% consistent condition. The increase in errors in the 75% consistent condition was because of an increase in false alarms (8% of the total 10% errors in sessions 4 and 5), with the majority of these false alarms (95%) confined to nontargets that were targets in the alternate block of trials. Thus, the increase appeared to result from a failure to suppress the influence of previous targets in the 75% condition for the participants with ID (Table 3). The fact that the increase in errors was restricted to a particular type of false

**Table 3** Mean per cent errors associated with false alarms for opposite targets (current nontargets) by participants with and without intellectual disability (ID) in the 75% consistent condition as a function of session and set size

| | With ID | | | Without ID | | |
|---|---|---|---|---|---|---|
| | Set size | | | Set size | | |
| Session | 2 | 3 | 4 | 2 | 3 | 4 |
| 1 | 0.1 (0.1) | 0.2 (0.1) | 0.2 (0.1) | 0.1 (0.1) | 0.1 (0.1) | 0.2 (0.1) |
| 2 | 0.7 (0.6) | 0.7 (0.8) | 1.2 (1.0) | 0.0 (<0.1) | 0.1 (<0.1) | 0.3 (0.2) |
| 3 | 1.2 (1.1) | 1.8 (1.3) | 3.6 (2.3) | 0.5 (0.2) | 0.2 (0.1) | 0.1 (0.1) |
| 4 | 2.8 (1.9) | 6.6 (4.0) | 8.7 (4.2) | 0.2 (0.1) | 0.2 (0.1) | 0.3 (0.1) |
| 5 | 7.5 (3.5) | 10.1 (5.2) | 12.7 (5.8) | 0.1 (<0.1) | 0.1 (0.1) | 0.4 (0.2) |

alarm would indicate that there was no general speed-accuracy trade-off.

The analysis of errors for the participants without ID indicated no significant differences of any kind.

## Discussion

A very different pattern of performance emerged for the participants with and without ID. The participants with ID did not exhibit a change in response time performance as a function of consistency of mapping. In the two consistency conditions, these participants exhibited the same decrease in the effect of set size across sessions. In accordance with the operational definition of automaticity used for the experiment, it was concluded that these participants exhibited automatic search and detection processes by the fifth session of practice in both conditions. While it may well be that their performance would not meet all criteria for 'pure' automaticity, the important result is that response time changes associated with practice did not differ for these participants as a function of consistent mapping. However, the response times of the participants without ID were significantly influenced by consistency of mapping. These participants took approximately twice as long to evidence automaticity in the search and detection task in the 75% versus 100% consistent condition. This is the typical finding for persons without ID (see Fisk & Schneider 1983).

The pattern of errors was essentially the opposite of what was observed for response times. The participants without ID were not affected by the consistency manipulation, exhibiting roughly equivalent error rates in the two consistency conditions. However, the error rates for the participants with ID were strongly affected by the consistency manipulation. It is possible that the difference in error rates reflects a strategic difference in the way that persons with and without ID actively inhibit responses associated with current nontargets in the detection task. The participants with ID were much more likely to respond to the wrong target than were the participants without ID. However, this tendency was only observed as practice increased. In essence, an automatic 'yes' response was being learned to both clothing and furniture when they were targets without sufficient inhibition being directed to these categories when they were occasionally nontargets. Hence, it does not appear that the participants with ID ignored instructions, but, rather they found it difficult to comply with instructions as training proceeded. In that way, the error results are similar to the notion of 'cognitive inertia' reported by Ellis and colleagues (e.g. Ellis *et al.* 1989; Ellis & Dulaney 1991). The participants with ID learned to respond 'yes' to all clothing and furniture and found it difficult to respond 'no' to these stimuli when they were not targets. The participants without ID continued to inhibit their responses to all nontargets, even if they were targets on previous trials. As a result, the development of automatic detection processes was slowed for the participants without ID.

The suggestion that individuals with ID exhibit difficulties associated with the active inhibition of nontarget stimuli is consistent with previous research of visual selective attention. Individuals with ID often exhibit greater interference from nontargets in visual tasks than do individuals of the same age without ID (e.g. Cha & Merrill 1994; Merrill & O'Dekirk 1994; Merrill & Taube 1996). What is new in this experiment is that differences in the ability to inhibit nontarget information may be partially responsible for the slower development of automatic processes for individuals with relative to those without ID. However, the evidence for this claim is indirect. I am suggesting that the faster learning to automaticity exhibited by the participants without ID in the 100% consistent condition was because of the fact that they learned to inhibit responses to nontargets as well as learned to respond to targets. When the usefulness of this process was disrupted by making nontargets of one display targets in another display, the development of automaticity was slowed. Because the participants with ID did not learn to inhibit responses to nontargets, the development of automaticity in the 100% condition was relatively slow at the start. In addition, they were therefore less affected (in terms of rate of learning) when the usefulness of inhibition processes was disrupted in the 75% consistency condition. The consequence was an increase in errors as learning proceeded in the 75% consistent condition.

It is important to note that it is not clear from these data whether the participants without ID actually increased their level of inhibition directed at the nontargets as practice increased, or whether they had been doing more to inhibit the nontargets all along. For differences in the inhibition of nontarget information to account for differences in the development of automatic processing, it will be necessary to demonstrate that the inhibition differences were evident from the start of practice and that inhibition processes were associated with all nontargets and not just those that were switched from target to nontarget and back throughout the experiment. Hence, there are still many questions that need to be addressed before this issued can be resolved. Unfortunately, the role of inhibition processes in the development of automatic search and detection processes in the 100% consistent condition may not be possible to test in a direct way. It may be possible to evaluate the role of inhibition processes in forms of learning that do not necessarily lead to automatic processing, such as visual search performance. In addition, it may be possible to evaluate the influence of changing nontargets across sessions on the development of automatic search and detection processes. If learning does involve learning not to respond to particular nontargets as well as learning to respond to targets, then changing nontargets across sessions should slow learning for individuals without more than individuals with ID.

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