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Developmental Factors in Visual Search: The Inhibition Deficit Hypothesis in a Feature-Integration Task

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Running Head: DEVELOPMENTAL FACTORS IN VISUAL SEARCH

Abstract

One of the most robust findings in cognitive functioning is that the elderly are more easily distracted by irrelevant information. This inhibition-deficit hypothesis may be useful in explaining older adults' deficits in visual search tasks. Treisman's Feature Integration Theory suggests that there are two ways to visually process information: parallel processing, an automatic process that does not require directed attention, and serial processing, which does. This study provides evidence for the role of inhibitory processes (and therefore frontal lobe involvement) in serial, but not parallel search. Six and ten year old children, undergraduate students, and elderly subjects participated in the experiment. Reaction times (RTs) were measured as subjects searched for a single target in one of three display types requiring serial, parallel, or both types of searches. The children and elderly's RTs were significantly longer compared to the undergraduate students. Non-significant trends were also seen in the conjunction condition. Children and elderly's RTs increased in the conjunction condition as the display size increased. Finally, elderly subjects showed faster RTs than the 6 year olds only. These results suggest a correlation between attention deficits and the development and degeneration of the frontal lobes.

Developmental Factors in Visual Search: The Inhibition Deficit Hypothesis in a Feature-Integration Task

The reduced inhibition hypothesis attempts to explain the findings that the elderly are more easily distracted by irrelevant information. According to this theory, older adults lose their ability to inhibit irrelevant information which leads to longer search processing times (Hartley, 1992; Hasher and Zacks, 1988). Because this inhibitory mechanism limits irrelevant information, it plays a central role in the operation of working memory and selective attention because it makes their operations more efficient (Hasher and Zacks, 1988). An inhibition deficit results in a longer processing time for irrelevant information in working memory (Hasher and Zacks, 1988; and Dempster, 1992), and will decrease the ability of the subject to switch attention from one target or category to another (Posner, 1987; cited in Hasher and Zacks, 1988). Hasher and Zacks (1988) believe this excess information receives more sustained activation than it would otherwise get in working memory. Because of the temporal timing of relevant and irrelevant information in working memory, information may have a weaker or poorer quality of encoding, and competition may result at retrieval (Hasher and Zacks,

1988). Thus, individuals with reduced inhibition show greater distractibility, make more inappropriate responses or take longer to make appropriate responses, and tend to be more forgetful.

One region of the brain, the frontal lobes, has been implicated in the inhibiting mechanism. Recently, it has been suggested that the lack of inhibition, or interference, may cause young children's working memory to be inefficient (Bjorklund and Harnishfeger, 1990). As children mature developmentally, their working memory becomes more efficient, and they have longer attention spans. This drastic change is evident when comparing preschool children to children in higher grade levels. Although the inhibition deficit theory seems valid, few research studies have examined the possibility that young children may have an inhibition deficit.

When looking at the differences in attention throughout the life span, it is interesting to note that when the changes in inhibition occur, the frontal lobes are undergoing change also. The frontal lobes are the last lobes to complete maturation in children. The frontal lobes grow rapidly from birth to the second year of life, and another growth spurt follows from 4 to 7 years of age (Dempster, 1992). After the age of seven, the frontal lobes grow slowly until puberty (Luria, 1973). This growth of the frontal lobes includes myelination and synaptic pruning (Reinis and Goldman, 1980). The frontal lobes do not reach full myelination until the early teenage

years (Reinis and Goldman, 1980). The myelinated axons propagate impulses more rapidly, so axons do not reach their full speed potential until around puberty. Also, synaptic pruning--the removal of extra or unproductive neural tissue--allows for axons to propagate impulses more rapidly (Dempster, 1992). Synaptic pruning allows for faster propagation because the network is more efficient . Thus, the adult efficiency in inhibition may relate to the maturation of these processes.

In late adulthood, the frontal cortex appears to decrease in its efficiency. This may be related to a decrease in the size, volume, and density of the cells in the frontal lobes, possibly due to diminished RNA levels which might induce defective protein metabolism (Uemura and Hartman, 1978; cited in Dempster, 1992). Also, Scheibel and Scheibel (1975) found: "a shrinkage or disappearance of horizontal dendrites that are thought to have inhibitory properties". Finally, the amount of cerebral blood flow decreases around the sixth decade of life for the frontal lobes, but the cerebral blood flow for other posterior lobes of the brain do not show such decrease (Shaw, Mortel, Meyer, Rogers, Hardenberg, & Cutaia, 1984). Because research data has implicated inhibitory processes in the frontal lobes and the frontal lobes are the last to fully develop and the first to deteriorate in later years of life, it is possible that the frontal lobes are involved in the development of the inhibitory process in children and the inhibitory process in the elderly.

If there is a correlation between inhibition and the development of the frontal lobes, then predictions can be made by testing different age groups on feature integration tasks. Treisman and Gelade (1980) introduced the feature integration theory of attention. The model is comprised of two stages; the feature extraction (or parallel) stage and the feature integration (or serial) stage. In the feature extraction stage, features are processed preattentively and in parallel across the visual field. It is not difficult to find the target among the nontargets because the target will "pop out" of the display, without initiating focused attention to find the object. However, in the feature integration stage of processing, the target possesses characteristics similar to the nontargets and therefore the target requires the subject to use attention to locate the target. Treisman and Gelade (1980) suggest that the serial stage of processing uses focused attention to combine simple features into complex objects. Focal attention is what Treisman called the "glue" that joins the separate features together. Non-target items may interfere with the target items if they have features that can be conjoined to form similar patterns to the target. Thus, if two stimuli each have one characteristic of the target, the stimuli may be confused with the target when conjoined. Therefore, attention is necessary for correct perception of conjunctions, and individuals with attentional deficits will experience difficulty with these types of tasks.

Treisman and Gelade (1980) tested their hypothesis with young adults by measuring the slope and the intercept of the function of reaction time to display size. Treisman and Gelade (1980) predicted that the parallel processing stage would produce a flat or nearly flat slope due to the pop out phenomenon, whereas the serial search would produce a steeper, positive slope. Their results correlated with these predictions, finding an insignificant increase in RT for the parallel processing search and a significant increase in RT for the serial processing search (Treisman and Gelade, 1980). From this, Treisman and Gelade (1980) concluded that the parallel searches did not require visual attention but serial searches did require visual attention.

Although Treisman and Gelade (1980) examined how features are combined to form complex wholes, their feature-integration theory may be used to measure the levels of inhibition deficit in various age groups. To determine possible differences in inhibition tasks between young adults and the elderly, Plude and Doussard-Roosevelt (1989) set up a feature search similar to that of Treisman and Gelade (1980) which tested three conditions. In the simple condition, the target possessed one of the nontarget's two possible characteristics, but also contained a unique characteristic of its own (see Figure 1).

Insert Figure 1 about here

Because of this unique characteristic, the target would pop out at the subject, thus measuring the preattentive or parallel processing aspect of attention. However, in the conjunction condition which measured selective or serial processing, the target possessed one characteristic from each of the two kinds of nontargets (see Figure 2). Because the target shared these traits,

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Insert Figure 2 about here

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serial attention needed to be used to locate the target item. Finally, the unconfounded condition was developed by Plude and Doussard- Roosevelt (1989) to determine if the serial processing condition of attention possessed any parallel processing characteristics. This was implemented by having two of the nontargets share the target's color, and the remaining nontargets would share the target's form (see Figure 3). In this

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Insert Figure 3 about here

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way, the nontargets that shared the target's form would be processed in parallel, while the three letters that shared the same color would be processed serially.

If the elderly produce a zero slope when measuring reaction time as a function of display size in the first condition, the elderly's preattentive processing would function like the young adult's processing which also produces zero slopes. The nearly flat slopes would suggest the popout phenomenon. If the elderly display larger slopes in the serial processing stage compared to the younger adults, this would suggest that the elderly have deficits in serial processing which implies an interference effect. Finally, the unconfounded condition measures both the serial and parallel processing conditions. If the elderly display longer RT in the serial processing condition, they should also have difficulty in the unconfounded condition, but not as severe because parallel that would inhibit most of the nontargets.

Plude and Doussard- Roosevelt (1989) measured the index of selective attention in this experiment using the slope of the function of reaction time to display size. In the feature search, both older and younger adults produced zero slopes, suggesting that the parallel processing stage is unaffected by age. In the conjunction search, age decrements in visual search were produced, suggesting that the serial processing

stage is affected by age. Finally, the unconfounded condition produced low or no increases in reaction time related to display size. This shows that both older and younger subjects cued in on the parallel processing condition similar to the target (color), and rejected the other features. The subjects then used serial processing to identify the target, so the reaction time did not increase with display size. Therefore, the feature integration theory divides visual information processing into age-sensitive compartments and gives a clear understanding of age changes in visual information processing (Plude and Doussard- Roosevelt, 1989).

Only recently has the feature integration theory been tested in children and young adults to study inhibition deficits in children. In the study by Thompson and Massaro (1989), three predictions were made about the reaction times of children and adults as a function of display size. The first prediction was that children's RTs would be slower in all conditions because children are slower in making decisions and motor responses. Next, RTs for children would be significantly longer because children are less efficient at visual search tasks. Finally, RTs for subjects in the simple condition should not show an increase as the display size increases because of the popout phenomenon.

The results of Thompson and Massaro's (1989)study correspond to the previous predictions. They found RTs were longer for preschool children than for adults in both simple and conjunction conditions. This overall main effect signals a developmental difference in response selection and execution for children. There was also a significant difference between the groups' RTs in the conjunction condition as display size increased. Thus, the children scan the targets slower than adults in feature-integration tasks, which fits the prediction that children search for targets less efficiently.

A different approach to assessing inhibition was used by Diamond et al. (in press, cited in Diamond 1991). They assessed the inhibitory control of action of 72 children (12 in each group from 3-8 years of age). These tests were: tapping (Luria, 1973), Stroop (Stroop, 1935), three pegs (Wozniack and Balamore, 1984; cited in Diamond, 1991), Simon Says, and simultaneous switch (Luria, 1973). Although it is questionable whether some of these tasks are accurate measures of inhibition (Simon Says and tapping), significant improvements were observed for all tests from 3-6 years, with a leveling off from 6-8 years. Diamond (1991) gave two possible explanations for this observation; either the children showed ceiling performances for the tasks, or the children reached a plateau where they remain for at least the next two years. Because the study did not include children beyond eight years of age, Diamond (in press) could not determine

which one of these reasons is correct. Diamond suggested further research relating to inhibition deficits in children needs to be done.

The above studies by Plude and Doussard Roosevelt (1989), Thompson and Massaro (1989), and Diamond (1991) suggest that children and the elderly possess significant differences in selective attention processing when compared to young adults. When considering the development of the frontal lobes and their implied link to inhibitory mechanisms, it is possible that these developmental differences result from the maturation and degeneration of the frontal lobes. However, a true comparison of these differences cannot be made because different methodologies are used in each study. Therefore, the purpose of this study was to provide a cross-sectional study which allowed for a reliable comparison of inhibition tasks between preschool children, undergraduates, and elderly subjects. Also, to obtain a clearer idea of the development of the inhibition process, a 10 year old age group was included.

The following hypotheses were tested. First, RTs in the simple condition for all subjects should not increase as display size increases, because this task does not require attentional processing. Second, in serial processing tasks that do require attention, the elderly and the children will produce significantly longer RTs than young adults when inhibiting nontargets. Third, the older children will perform significantly better than the younger children due to

the maturation of the frontal lobes and therefore the greater maturation of the inhibition process. This result would answer the question posed by Diamond (in press) regarding whether 6-8 year old children improve in their performance of inhibition tasks. Fourth, children and elderly will produce longer RTs in serial searches as the display size increases, suggesting greater interference as the number of distracters increase. Finally, the elderly will perform better than the children possibly because they possess an inhibition mechanism, but it is not working at full efficiency, whereas children's inhibition mechanism is not fully developed. Elderly subjects also have experience and compensatory mechanisms to aid their performance.

Method

Subjects

Fifty-seven subjects participated in the study: two preschool children, two ten-year-old children, 35 undergraduate students, and 18 elderly subjects from a medium-sized midwest city. The preschool and grade school children were recruited from the elementary schools in the surrounding community and informed consent was obtained from the child's legal guardian. The undergraduate students attended Illinois Wesleyan University, and received extra-credit in class as an incentive for their participation. The elderly were volunteers from local retirement apartments and received $10 for their participation.

Before the experiment began, each subject was informed that 20/20 vision was required. Since the letters in the instructions on the computer screen are the same size as the stimuli in the computer program itself, it is assumed that if the subject can read the instructions and reiterate them out loud, the subject has met the visual requirements.

Apparatus

The stimuli were displayed on a Macintosh Centris 610 for the young adults, and on a Macintosh PowerBook 170 for the elderly and the school children. The Macintosh PowerBook was necessary since the schools and retirement centers do not have compatible computers, and because it is difficult for most of the elderly subjects to find transportation. Also, most of the children's parents preferred testing in their home. The stimulus displays consist of either 5, 10, or 15 elements, with the target displayed equally around the central fixation point (a + sign). Each letter was 3 mm X 5 mm and the target was presented randomly but equally in each hemisphere. The equal representation around the central fixation point was ensured by a grid made of a small circle surrounded by a larger circle, with their centers being the central fixation point. The circles were divided by an "X", thus totaling eight sections.

Design

The experiment consisted of three crossed factors. They are display size (either 5, 10, or 15 letters), age (6 year olds, 10 year olds,

undergraduates, and elderly), and condition (simple, confounded, or unconfounded). The distance between the center of the subject's foreheads to the center of the screen (the fixation point) was 60 cm. The subjects were allowed 16 practice trials to become familiar with the tasks and to understand what was expected of them. Trials varied by condition, display size, and target present/absent. There are 36 trials in each block for a series of eight consecutive blocks, which totals 288 trials overall. In each block, all unique combinations of factors were present, and the targets were dispersed equally between the eight hemispheres. The blocks were divided by one minute breaks to diminish the possibility of fatigue. Children received longer breaks and were allowed to color during the breaks.

The stimuli consisted of two dimensions, orientation (letters in the upright or horizontal orientation), and form (capital T's and P's). The subjects performed a search for a single target, a lazy T (a T in the horizontal orientation), which was equally presented in the hemispheres throughout the trials. The trials were counterbalanced for all subjects. The subjects found the target among one of the simple, conjunction, or unconfounded conditions. The following are examples of the conditions seen in a trial:

Simple: Nontargets did not share the target's orientation, but did share the target's form (see Figure 1).

Conjunction: Half of the nontargets share the target's form while the other half of the nontargets share the target's orientation (see Figure 2).

Unconfounded: Two of the nontargets share the target's orientation, while the remaining spaces of the display are filled with nontargets that share the target's form (see Figure 3).

Procedure

The subjects were given the Kaufman Brief Intelligence Test before initiating the computer program to ensure that all subjects are around the normal range of basic intelligence. After this test, the subjects were led into the computer room where the experiment began. The instructions appeared on the screen for the subjects to read and ask questions (the instructions were read off the screen to each child). A "+" along with a warning tone occurred 500 ms before the trials were presented so the subjects could focus on the central fixation point. The subjects were to determine if the horizontal T is present in the trial. If the T was present, the subject pressed the "yes" button, and if the target was absent, the subject pressed the "no" button. The subjects were encouraged to press the button as quickly as possible while keeping errors at a minimum. After each trial, the subjects heard feedback in the form of a high-pitched tone if they are correct, and a low-pitched tone if they are incorrect. The feedback allows the subject to be aware of the errors made and to adjust their reaction times accordingly. After the subjects read the

instructions and had no further questions, the subject pressed the "yes" button to begin a series of eighteen practice trials. After the practice trials, the subjects were again asked if they had any questions. If not, the subjects began the experiment which took about 25 to 30 minutes. After the experiment was completed, the subjects were debriefed on the purpose of the study, parallel and serial visual processing, and the other age groups involved in the study.

Results and Discussion

Each subject's mean RT was calculated. Cut-off scores were established if the subject's RT average was 5% above their group mean. Reaction times two standard deviations above the group mean were also disregarded. Because there were only two children in each of the 6 and 10 year old groups, a separate ANOVA compared the two groups of children, and another ANOVA compared the undergraduates and elderly. The ANOVAs manipulated display size, display type, and subject group.

There was a significant main effect of age when comparing the two groups of children and the undergraduates to the elderly ($p < .0001$). Six year old children were significantly slower than the 10 year old children, and the elderly were significantly slower than the undergraduates (see Figure 4). These trends correlate with what was

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Insert Figure 4 about here

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predicted from the inhibition deficit hypothesis. If inhibition is located in the frontal lobes, the developing and aging processes of the frontal lobes would also correspond with these results. As the children and their frontal lobes mature, their RTs would be quicker, suggesting a more efficient inhibiting system. As adults mature and their frontal lobes degenerate, their RTs would become delayed.

Condition was also a significant main effect when comparing the undergraduates with the elderly ($p < .0001$). Both the elderly and the undergraduates produced longer RTs in the conjunction condition compared to the simple condition (see Figure 4). This result corresponds with the prediction that the conjunction condition produced longer RTs because serial processing was required. Because parallel processing was used in the simple condition and the pop out phenomenon occurred, long RTs were not required to find the target.

In addition to significant results, non-significant trends are also important. One trend of this type occurred in the conjunction condition and was only seen in the elderly and the 6 year olds. These groups produced longer RTs in the conjunction condition as the display size increased (see Figure 4). Possibly due to frontal lobe involvement in attentional processes, the elderly and 6 year olds with

inefficient frontal lobes may have more of a problem finding the target as the number of nontargets increase.

In contrast to the differences seen between 6 year olds and the elderly, 10 year old children produce results similar to the undergraduate students (see Figure 4). This finding supports the idea that 10 year old children have almost fully developed inhibition mechanisms, and answers the questions that Diamond asked in her 1991 study. These results suggest that children after 8 years of age do not plateau, but still have developing inhibition mechanisms. Because the older children's RTs in all conditions are slightly but not significantly longer than the undergraduates, the developmental process may still be going on after 10 years of age, but where that process portrays the undergraduates is still unknown.

Another non-significant trend that supported the hypotheses was the elderly showing faster RTs than the 6 year olds only (see Figure 4). The elderly's faster RTs may result from a developed but somewhat degenerating frontal lobes, whereas children do not have fully developed frontal lobes. When comparing the elderly to the 6 year olds who have an underdeveloped inhibition mechanism, the elderly did find the target faster. Elderly subjects also were expected to perform better than the younger children because of experience and compensatory mechanisms. Reduced inhibition occurs gradually, and as an inhibition deficit emerges, strategies for counteracting the problems also emerge. Because of this experience,

elderly may perform better than inexperienced children in Treisman-like tasks.

Because of the variance in the RTs of elderly subjects and children, significance was not obtained in the above trends. High levels of variance in RTs for elderly subjects possibly resulted from different stages of frontal lobe degeneration. Not all elderly people experience significant degeneration in the frontal lobes, and if degeneration is present, elderly experience it in different areas of the frontal lobes and at different rates. Also, elderly individuals compensate differently, which introduced more variance. Because the elderly sample was random, variance in that group was high. Significant results for these trends may occur when more elderly subjects are tested and compared. The same reasoning may be used for the children. Children progress differently during development, and variations may occur to skew results. Although predicted trends were also seen with the children, more children are needed to determine if significant differences exist in other variables of the study. Undergraduate students, however, produced smaller variance which possibly resulted from maturation of the frontal lobes.

These results support the conclusions of other studies that elderly and children tend to have greater difficulties than young adults when required to discriminate between nontargets to find a specific target (Hasher and Zacks, 1991; McDowd and Oseas-Kreger, 1991; Plude and Doussard-Roosevelt, 1989; 1986; Thompson and

Massaro, 1989; Tipper, 1991; & Shaw, 1991). These results suggest greater interference in the children and the elderly, possibly due to an inhibition deficit. Because the frontal lobes have been implicated as the controlling factor of the inhibition process, it is likely that the development and degeneration of the frontal lobes corresponds to the subject's performance on inhibition tasks.

Although this evidence supports the previously stated hypotheses, there are a few problems with the study. One problem relates to the computers used; the Macintosh PowerBook 170 may have a higher variability when recording the subject's reaction times. Although accuracy is important when dealing with milliseconds, a much higher reaction time is expected in elderly and children. Thus, testing children and elderly subjects with the Macintosh PowerBook should not skew the results towards the hypotheses. Another problem with the experiment relates to the fact that the elderly and the children were not tested in the laboratory, as the young adults were. However, each subject was tested in a quiet and distraction-free setting. Finally, the methodology of the study required 288 trials to each subject. Because the program took 25-30 minutes to complete, fatigue may result. To counteract this inevitable problem, one-minute breaks were programmed between each block. The subjects were allowed to relax and move around. If a break was not long enough, the subjects were allowed to postpone the start of the next

trial until they were ready. Therefore, fatigue should not have affected the outcome of the experiment to a significant degree.

The low number of children participating in the study also poses problems. Unfortunately, low response rates from the children's parents accounted for only four children in the study. Obviously more children are needed to make stronger comparisons between subjects. In addition to more elderly subjects, more children are currently being tested and then one ANOVA will be used to compare all groups.

Despite these minor problems, this cross-sectional study allowed for a comparison between young children, older children, undergraduates, and the elderly. No other cross-sectional studies have been reported using one task to measure inhibition. This study successfully allows for comparisons across age groups and suggests a strong developmental correlation between the frontal lobes and inhibition.

The next step in inhibition research is determining a strong link between the frontal lobes and inhibition. The fact that the inhibition rise and decline corresponds to the development of the frontal lobes is not enough to imply that the inhibitory mechanism is localized to the frontal lobes. To strengthen this case, frontal lobe patients should be tested with this methodology to determine if the damage to the frontal lobes correlates to the results of the elderly. Thus, if frontal lobe patients produced longer RTs than the elderly,

there is a stronger chance that the frontal lobes are directly related to inhibition and not indirectly affecting another mechanism of inhibition.

In closing, this research offers support for implementing the feature-integration theory when measuring inhibition tasks in visual attention. The methodology allows for a comparison between the age sensitive and age insensitive tasks experienced with inhibition tasks. It also allows for a clearer understanding of developmental changes in inhibition tasks using the visual attention processes.

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Figure Caption

Figure 1. An example of the simple condition which requires parallel processing.

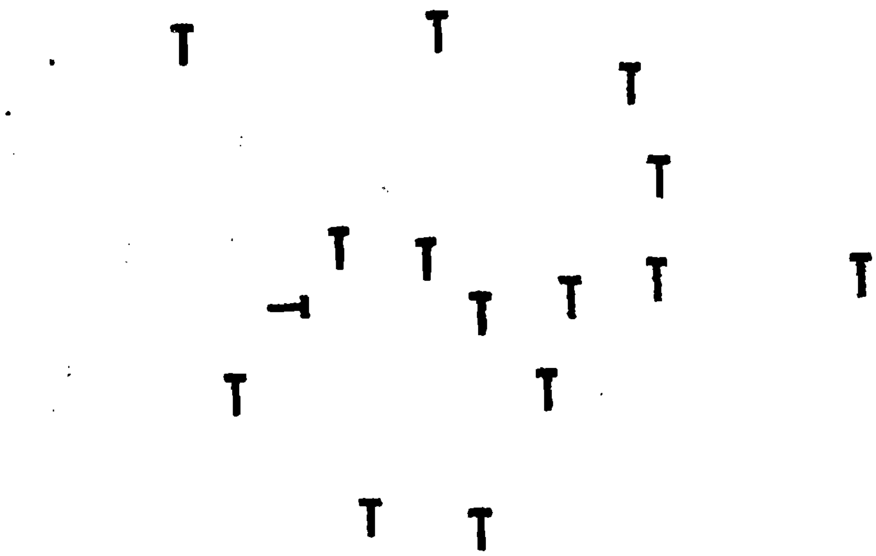

Figure Caption

Figure 2. An example of the conjunction condition which requires serial processing.

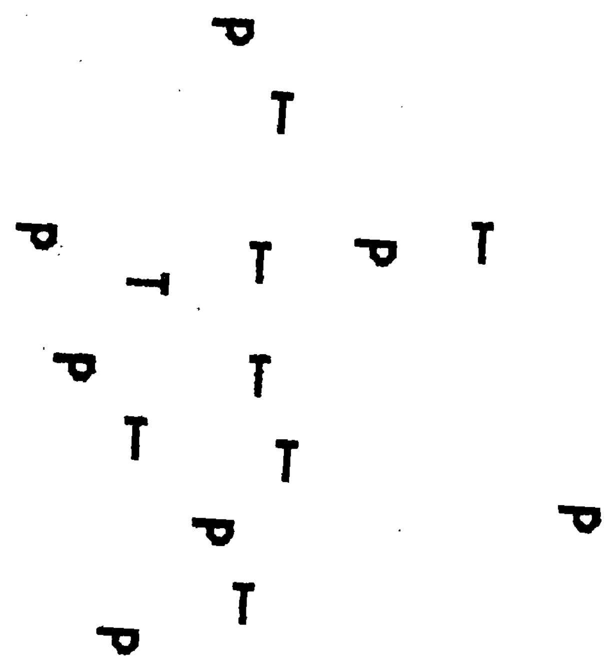

Figure Caption

<u>Figure 3</u>. An example of the unconfounded condition which requires both parallel and serial processing.

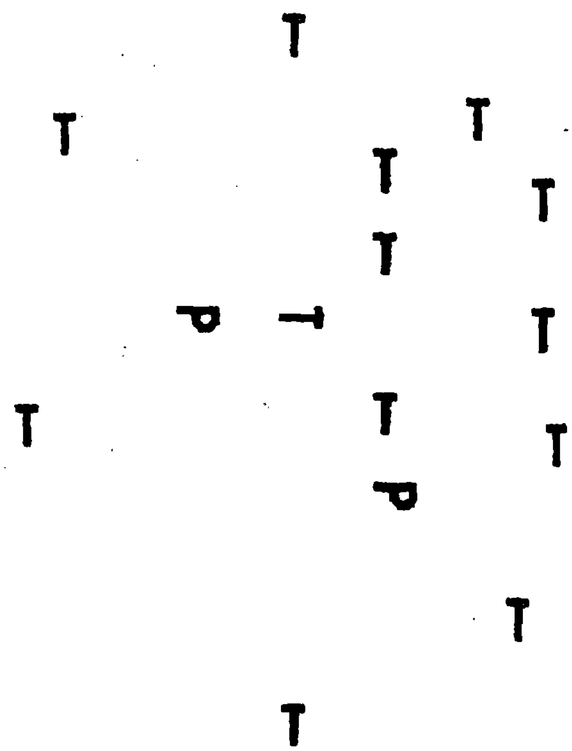

Figure Caption

Figure 4. Mean reaction time as a function of age group, condition type, and display size.

Figure 4. Plot of reaction time for Group x Type x Size