Flanker Interference in Younger and Older Adults:

Does Training Influence Focusing of Attention?

by

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Abstract

This study investigated the influence of training on interference in younger and older adults using the Eriksen flanker task. Does flanker interference differ with age and, as practice progresses, does the pattern of interference change? Younger and older adults were given five sessions of training on the flanker task over five successive days. On each trial, participants saw a central target letter flanked vertically by two flanker letters; the flankers could be either compatible or incompatible with the target. Participants were to respond to the identity of the central letter, ignoring the flanker letters. Although older adults were slower overall than younger adults in responding, the two groups showed virtually identical overall benefits from practice. Critically, the two age groups showed equivalent and constant interference due to incompatible flankers at all stages of practice. In the flanker paradigm, aging slows response execution without affecting attention within a trial or learning across trials.

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Table of Contents

Selective attention plays a vital role in our everyday functioning. However, this seemingly straightforward skill is anything but simple. We are able to pay attention to relevant information and to successfully screen out irrelevant information. That this skill is learned is particularly evident from developmental research where children improve in their ability to select (e.g., Gelman, 1969) and from research on clinical disorders such as schizophrenia where adults suffer dramatic losses in their ability to select (e.g., Meichenbaum & Cameron, 1973). One can imagine that paying attention actually involves different processes, such as being aware of information, locating and identifying relevant information, and resolving any conflicting information or thoughts. Any unexpected deviation from normal development may result in impairment of everyday functioning. Given that this skill is learned in childhood and can be lost in adulthood, an intriguing question is whether this skill can be improved with training and, if so, how it changes with practice or experience.

The research on automaticity in the 1970s certainly indicated that training played a role in attention (see, e.g., Schneider & Shiffrin, 1977). More recently, studies have gone on to explore training benefits as a function of such features as the stimulus specificity of the training (e.g., Kelley & Yantis, 2009), the reinforcement associated with the training (Della Libera & Chelazzi, 2009), and a variety of other dimensions of training. Moreover, programs of attentional training have begun to be investigated, programs that might benefit individuals with attentional problems, as in the work of Posner and his colleagues (see, e.g., Tang & Posner, 2009).

The ability to resolve conflicting information and to ignore irrelevant information has been thought to be the main function of the executive attention network, one of three attentional networks (Posner, 1980). This attention network, associated with the anterior cingulate cortex and the lateral prefrontal cortex (Posner, 1980), is particularly important because of its role in regulating responses and in resolving conflicts, including thoughts, responses, and feelings. For example, error detection and decision making are both functions of this network. Recent research has shown that training can improve attention and executive control (for overviews, see Green & Bavelier, 2008; Tang & Posner, 2009). Training programs such as the Attention Process Training (APT) program have led to specific improvements in executive functioning in adults with acquired brain injury (Sohlberg, McLaughlin, Pavese, Heidrich, & Posner, 2000) and in children with ADHD (Kerns, Esso, & Thompson, 1999).

Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) examined the effects of five days of training using the Attention Network Test (ANT), a behavioural measure of the three attentional networks. They found that six year old children who trained on various anticipation, stimulus discrimination, and conflict resolution tasks were better able to resolve conflict (i.e., they showed a greater reduction in conflict response times on the ANT) than were children who did not undergo training. In addition, the post-training scores were similar to those of adults. Similarly, four year old children in the training group showed brain activity like that of adults: There was larger negative amplitude of the N2 component (i.e., the second negative deflection occurring around 300-500 ms) in the frontoparietal region associated with the anterior cingulate for incongruent trials. The N2 component has been found in adults to be indicative of conflict-related activity (particularly the incongruent trials) in flanker tasks (Rueda et al., 2005). Rueda et al. (2005) found that, although at the age of 6 children's brain activity in prefrontal cortex was already similar to adults' brain activity without training, training promoted more activity in prefrontal regions. This suggests that the abilities to regulate attention and to resolve conflict develop particularly quickly between two and seven years of age, but also that additional training can be beneficial at both the behavioural and neural level.

Although executive attention functioning is relatively established at an early stage in development (Rueda et al., 2005), training in adulthood on attention tasks or simply playing action video games can help to improve selective attention performance. For example, Green and Bavelier (2003) found that young adults who played video games for 10 consecutive days showed a greater reduction in the attentional blink, a measure of attentional failure to detect a target in a rapid serial visual presentation, than did young adults who did not play the games. They also found that interference in young adults declined with 10 consecutive days of training on the ANT. These studies suggest that attention training even in adulthood can be beneficial for the ability to resolve conflict.

One population that can potentially benefit from attention training is older adults. As one ages, cognitive functioning begins to decline and the task of extracting relevant information and ignoring irrelevant information becomes more difficult (Zeef, Sonke, Kok, Buiten, & Kenemans, 1996). One theory of attention is that attention is like a "zoom lens" (Eriksen & St. James, 1986) in which the breadth of attention is based on how informative the irrelevant information is (Brown & Fera, 1994). However, as we age, we are less able to focus our attention and our attention spotlight becomes wider (Zeef & Kok., 1993). This means that the more irrelevant information that falls in the field of view, the more one has to exclude the irrelevant information to avoid unnecessary distractions. Jennings, Dagenbach, Engle, and Funke (2007) used the ANT to examine the three attentional networks in older adults. Older adults were generally slower than younger adults, but benefited when the cues became more informative. Examining the executive attention network, older adults showed a greater negative impact of incongruent flankers than did younger adults. However, when speed was taken into account, this greater congruency effect in older adults was eliminated. It seems that older adults show generalized slowing and that this broadly affects their functioning of executive attention, but it is less clear whether particular attentional skills are impaired by aging.

From the above studies, we would expect that older adults should suffer greater interference from irrelevant information than younger adults. If this is the case, it would be especially beneficial if training could help older adults "zoom in" their attention and exclude unnecessary information, thereby reducing the decline in cognitive functioning ordinarily seen with aging. As Brown and Fera (1994, p. 53) noted, it is quite intuitive that "when multiple blocks of trials are run, it is to be expected that subjects will be better at focusing in a second block than in a first block." If older people can learn to deal with resolving conflict, then we would expect reduced interference with practice. Younger people might start with less interference but might also be able to learn to reduce interference with practice.

With more and more research on training, an important question is how to make training effective. Studies have used various attention tasks to examine executive attention, from simple familiar cognitive tasks to elaborate video games. One of the most popular attention tasks, perhaps because of its simplicity, is the Eriksen flanker paradigm. This task is used to measure the influence of distracters on targets (see the overview in Eriksen, 1995). Typically, on each trial, participants are presented with a central target letter with adjacent flanking distracter letters and are asked to identify the central target and to ignore the flankers. There are two types of trials—compatible trials, in which the response to the flankers and the target is the same—and incompatible trials—in which the response to the flankers and the target is different. Interference is measured by the difference in response time between incompatible trials and compatible trials.

Studies using the Eriksen flanker paradigm have shown that a number of experimental manipulations affect the size of interference. For example, the greater the distance between the attended target and the to-be-ignored flankers, the more the effect of congruency is reduced (Yantis & Johnston, 1990; Zeef et al., 1996). Cerella (1985) found that when flanker-to-target distance was small, there was greater interference in older adults than in younger adults. However, interference was reduced when the flankers were placed in eccentric locations (e.g., greater than 3 degrees from the target). Another factor that plays an important role in flanker interference is how informative the flanker is. Brown and Fera (1994) found that when the flankers became less informative (i.e., when only one flanker was correlated with the correct response), there was consequently less incentive to attend to the flankers, and therefore interference was reduced.

In addition to the factors that do affect the magnitude of interference, other studies have found that certain manipulations do not change the magnitude of interference. For example, flanker interference does not seem to be affected by whether the flankers are placed top and bottom or left and right (Brown & Fera, 1994). This is important because it suggests that interference in the Eriksen flanker task is not due to where the flankers are placed but rather to the proximity of the flankers to the targets (Zeef et al., 1996). In the present study, I was interested in whether training can affect flanker interference in younger and older adults differently when the target and the to-be-ignored flankers are very close, that is, well within the attentional focus of both younger and older adults, and the flankers are uninformative (i.e., 50% of the time they agree with the target, 50% of the time they disagree with the target).

A couple of studies have examined flanker interference and aging using the Eriksen flanker task, but the available research is limited and inconsistent. Zeef and Kok (1993) used both behavioural and event-related potentials (ERPs) to examine whether older adults are slower in extracting information. The ERP measures were to evaluate the onset of lateralized readiness potentials (LRP), which reflect when sufficient information is extracted. Behaviourally, both younger and older adults showed interference but older adults showed more interference. For older adults, ERP data showed an incorrect LRP peak followed by a later onset of the correct LRP peak in the incompatible condition. This suggests that the general slowing seen in response times in older adults could be due at least partly to incorrect activation of central motor processes. In addition, the early incorrect LRP peak indicates that older adults are more sensitive to flanker information at an early stage, which consequently suggests that there is a "decrease in selectivity of visuospatial attention and stronger interference of distracting stimuli" (Zeef & Kok, 1993, p. 149).

Similarly, Zeef et al. (1996) found that there was a delay in response time associated with incompatible trials, accompanied by an incorrect response activation (measured by a positive LRP). This was followed by a later correct lateralization for older adults. Younger adults were found to have a later onset of correct LRP but earlier response activation than older adults (measured by electromyographic, EMG, onset). The results showed that older adults had a larger response conflict effect than younger adults (Zeef et al., 1996).

The finding that the delay in response time and later LRP onset is associated with incompatible trials in Zeef and Kok (1993) and Zeef et al. (1996) is particularly relevant because it suggests that training should affect incompatible trials more than compatible trials. There is one finding consistent with this suggestion: Ishigami and Klein (2010) found that flanker interference was reduced over 10 sessions, with this executive effect due mainly to decreased response time in the incongruent condition. These findings are supportive of the possibility that participants can come to ignore flankers over time.

Although greater interference in older adults seems most logical, particularly due to their increased sensitivity to flankers at an early stage of processing, this result has not been universal in studies that have investigated the flanker task without manipulating training. Some of these studies have found no difference in interference once generalized overall slowing was controlled for. Thus, Jennings et al. (2007) found no difference in the amount of interference between younger and older adults. Wild-Wall, Falkenstein, and Hohnsbein (2008) also found that older adults did not have greater flanker interference compared to younger adults, even though older adults exhibited general slowing. However, it also seems possible that, when it is observed, increased sensitivity to flankers may be an indicator of older adults adopting a different strategy that may require more time than that required by younger adults.

Wild-Wall et al. (2008) found that, compared to younger adults, older adults showed a negative deflection after the N1 component, suggesting that older adults may process displays differently. It has been found that older adults show a reduced error rate on the flanker task compared to younger adults (Wild-Wall et al., 2008; Zeef et al., 1996), suggesting that older adults place a more strategic emphasis on accuracy (Zeef et al., 1996). The initial incorrect LRP onset found in older adults in Zeef et al. (1993) also suggests that younger and older adults resolve conflicting information differently. The findings that older adults have a delay in motor preparation, have a wider attentional focus, and have more difficulty extracting relevant information, together suggest that older adults may adopt different strategies to compensate for these deficiencies when resolving conflicting information (Wild-Wall et al., 2008; Zeef & Kok, 1993; Zeef et al., 1996). If the two age groups react to conflicting information differently, an interesting question that we want to address in the present study is whether training on flanker interference can affect younger and older adults differently.

The main purpose of the present study was to address whether training could help younger and older adults improve the functioning of the executive attention network. Of course, older adults should be overall slower in response times (cf. Salthouse, 1996). More specifically, though, could training help to reduce interference in younger and older adults, and would any observed reduction differ in the two age groups? Participants were asked to come in for five days to train on an Eriksen flanker task, a simple task that is typically used to examine conflict activity in the executive attention network. They were to identify the central letter target (H or S), ignoring the vertical flankers (H or S) above and below the target. We were interested first in determining whether older adults do or do not show more interference than younger adults, given the inconsistency in the literature. Then, over five consecutive days of training, if they could learn to selectively attend more effectively, we expected flanker interference to decline for both the younger and older adults. Based on the limited available literature, we also expected that training would affect incompatible trials more than compatible trials. Of particular interest, though, was whether interference patterns would be different in older and younger adults, both generally and as a function of practice. We also wondered whether, if older adults have more difficulty focusing attention, training might benefit older adults more than younger adults.

Method

Participants

Twenty-three younger adults and twenty-five older adults took part in this study. For younger adults, ages ranged from 18 to 22, with a mean age of 19.5 years and a standard deviation of 1.1. For older adults, ages ranged from 67 to 88, with a mean age of 75.8 years and a standard deviation of 5.9. The younger adults were students at the University of Waterloo. The older adults were recruited from the Waterloo Research in Aging Participant (WRAP) pool at the University of Waterloo. All participants were healthy, had normal or corrected to normal vision, and spoke English fluently. For participating, upon completion of all five sessions, younger adults were given two course credits along with $10; older adults were given $40. Informed consent was obtained from all participants.

Apparatus

The experiment was carried out using E-prime software (Psychology Software Tools, Pittsburgh, PA, USA) with all responses recorded through the program. Stimuli were presented in font size 16 on a PC computer, with participants seated approximately 26 inches from a 15-inch CRT screen. Stimuli were presented in a three-letter vertical array subtending a visual angle of 1.9˚.

Design

The design was a 5 (sessions) x 2 (compatibility: compatible vs. incompatible) x 2 (age: younger vs. older) factorial design with sessions and compatibility both as within-subject variables and age as the between-subjects variable.

Procedure

Participants were informed that the experiment would last approximately two hours total across five consecutive days. On each day, participants performed the flanker task for approximately 20 minutes. On each trial, they were shown three letters—a central letter and two flanker letters that appeared above and below the central letter. Participants were told to ignore the flanker letters and to respond only to the central letter by pressing the “z” key if the central letter was an H and the “m” key if the central letter was a S.

There were five sessions over five consecutive weekdays. Each session consisted of 8 blocks of 24 trials, for a total of 192 trial per session and 960 trials overall. The total number of trials across five days was similar to previous studies that showed practice effects on the flanker task with four blocks of 232 trials (e.g., Brown & Fera, 1994, used 4 blocks of 232 trials per block for a total of 928 trials overall). In addition, the separation of total trials into smaller blocks was to address whether a small amount of practice per day would reduce interference.

Within each trial, a fixation appeared for 1000 ms followed by a blank for 1000 ms, followed by the flanker stimulus which remained on the screen until the participant responded with a key press. The three letters of the flanker stimulus consisted of a central target letter (H or S) and two flanker letters (both H or both S) appearing simultaneously above and below the target letter. Thus, there were four possible stimuli, two compatible (HHH or SSS) and two incompatible (HSH or SHS), with each stimulus occurring equally often in each block. This procedure is displayed in Figure 1. All blocks were made up of 12 compatible and 12 incompatible trials in a unique random order.

In every session, four practice trials preceded the start of the actual experiment of 8 blocks of 24 trials. Practice trials consisted of two compatible and two incompatible trials presented in alternating order. Feedback indicating “correct” or “incorrect” was given after each practice trial.

Results

Error Data

The error data are shown in the bottom panel of Table 1. Mean percentages of errors were calculated for each participant and submitted to a 2 x 2 x 5 mixed analysis of variance (ANOVA) with age (young, old) as the between-subjects factor and compatibility (compatible, incompatible) and session (days 1-5) as the within-subject factors. There was a reliable main effect of age, with younger adults making more errors than older adults (M = 2.79% vs M = 0.46%), $F(1,46) = 32.10$, $MSE = 20.15$, $p < 0.001$, partial $\eta^2 = 0.41$. There was also a reliable main effect of compatibility, with more errors made on incompatible trials than on compatible trials (M = 2.22% vs M = 1.03%), $F(1,46) = 25.74$, $MSE = 6.57$, $p < 0.001$, partial $\eta^2 = 0.36$. The main effect of session was not reliable, $F < 1$. There was also a significant interaction of age with compatibility in which the difference in errors between the incompatible and compatible conditions was greater for younger adults (M = 2.20%) than for older adults (M = 0.18%), $F(1,46) = 18.71$, , $p < 0.001$, partial $\eta^2 = 0.29$). The only other interaction to note was that of session with compatibility, which was marginal, $F(4,184) = 2.21$, $MSE = 6.31$, $p = 0.07$, partial $\eta^2 = 0.05$). The interaction of session with age, and the three-way interaction, both were nonsignificant, both Fs < 1.87, ps > 0.12.

Response Time Data

The critical data were the response times. For compatible and incompatible trials for each session, a very few extreme values (greater than 4000 ms) were first trimmed from the correct response time data. For younger adults, across all participants and trials, there were only three compatible trials and six incompatible trials in which response time exceeded 4000 ms. For older adults, there were only three compatible trials and four incompatible trials that exceeded 4000 ms. These extremely long trials represented only a miniscule proportion (0.04% for younger adults and 0.03% for older adults) of the 960 trials performed by each participant across sessions. Afterward, for both compatible and incompatible trials across five days, response times that exceeded 2.5 standard deviations from the mean of a condition were eliminated for each participant. Overall, 2.9% of the response time data were trimmed from both the younger adults and the older adults using this criterion.

The resulting mean correct response times are shown as a function of age, compatibility, and training, in both Figure 2 and the top panel of Table 1. These data were submitted to a 2 x 2 x 5 mixed ANOVA, with age (young, old) as the between-subjects factor and compatibility (compatible, incompatible) and session (days 1 to 5) as the within-subject factors. All three main effects were significant, but none of the interactions were, simplifying interpretation. As anticipated, older adults (M = 714 ms) were considerably slower to respond than were younger adults (M = 535 ms), $F(1,46) = 31.20$, $MSE = 122780.15$, $p < 0.001$, partial $\eta^2 = 0.40$. There was also the usual main effect of compatibility, with interference evident from incompatible trials (M = 641 ms) being slower than compatible trials (M = 608 ms), $F(1,46) = 179.77$, $MSE = 33264.62$, $p < 0.001$, partial $\eta^2 = 0.80$. And there was a reliable main effect of session, $F(4,184) = 5.25$, $MSE = 4910.48$, $p < 0.01$, partial $\eta^2 = 0.10$. The reliable linear trend for session, $F(1,46) = 6.83$, $MSE = 11390.59$, $p < 0.05$, partial $\eta^2 = 0.13$, indicated that learning occurred across sessions. All of the interactions—the three two-ways and the three-way—were nonsignificant, all Fs < 1.14, ps > 0.30.

Discussion

We addressed two issues in this article—whether training can reduce interference and whether the amount of interference over time differs for younger and older adults. It is clear that older adults are certainly slower overall, consistent with a great many prior studies (see Salthouse, 1996). Also, both younger and older adults showed generalized learning, becoming faster in responding to the central letter over training sessions. However, the flanker effect was not influenced by training: Interference remained virtually constant over training, and was very similar for younger and older adults. The simple conclusion would be that flanker interference is constant as a function of both age and training: The attentional cost of incompatibility across days is not exaggerated by age, despite overall slowing and reduced error rates in older adults .

General Slowing and Interference in Older Adults

The present findings are consistent with studies that found older adults to be slower in executing cognitive processes than younger adults (e.g., see the overview of processing speed theory, Salthouse, 1996) and that suggested that older adults tend to adopt a different strategy than younger adults (Zeef & Kok, 1993; Zeef et al., 1996). Overall, older adults were about 179 ms slower than younger adults in response to the central letter across all sessions. In addition, though, older adults showed reduced error rates relative to younger adults. Whereas for older adults error rates were similar for both incompatible and compatible trials, for younger adults, error rates for incompatible trials were greater than those for compatible trials.

The general slowing in older adults coupled with reduced error rates on incompatible trials suggests a difference in strategy, with older adults placing a strategic emphasis on accuracy. This difference in strategy has also been found in other studies demonstrating that, when there is spatial uncertainty for targets, younger adults was more willing to increase the spread of their attention at the cost of processing additional flankers (e.g., Madden & Gottlob, 1997). The switch to a more conservative criterion in later age may be a compensatory measure for the inefficient processing associated with cognitive aging. For example, not only is cognitive aging associated with a general reduced speed of processing, but cognitive aging is also associated with an overall larger spotlight of attention (Eriksen & St. James, 1986), and possibly with reduced ability to inhibit irrelevant information before it reaches working memory access (Hasher & Zacks, 1988). Egeth (1977) found that the size of attentional focus varied with the speed of processing such that responses were faster when the focus size was small than when the focus size was large. When the spotlight of attention is larger, the resulting problem is that there also is more irrelevant information (e.g., flankers) to exclude from the focus of attention to avoid unnecessary distractions. Studies have found that if older adults are given an alerting cue prior to responding, it is possible to switch older adult's response criterion back to a more liberal criterion (Fernandez-Duque & Black, 2006). Allocating more time and the use of a more conservative criterion can benefit older adults in terms of compensating for any increased attentional costs associated with cognitive aging.

This compensatory effect is clearly seen in the present study in which older adults did not differ from younger adults in the effect of flanker interference in response times. The age x compatibility effect in response times was not significant. Although this finding contradicts some studies that have reported that older adults are more distracted than younger adults (e.g., Zeef & Kok, 1993; Zeef et al., 1996), it concurs with other studies that have reported that the compatibility effect does not increase with age (Madden & Gotlob, 1997; Jennings et al., 2007; Fernandez-Duque & Black, 2006). In a cross-sectional study examining the orienting and executive attention network, Waszak, Li, and Hommel (2010) found that older adults showed a decrease in conflict resolution. However, Jennings et al. (2007) found that, when general slowing was taken into account, the interaction between age x compatibility was eliminated. Similarly, Fernandez-Duque and Black (2006) found that when overall speed was taken into account, older adults showed a smaller congruency effect than young adults on a similar flanker task.

It still is not entirely clear why there are discrepancies regarding the interference effect for younger and older adults. The absence of an age x compatibility effect in the present study is in accordance with other studies (e.g., negative priming studies) that when older adults were shown concurrently presented distracters, they did not differ from younger adults in their susceptibility to interference (Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994). This suggests that, on some levels at least, older adults can ignore distracters quite successfully.

Training Across Younger and Older Adults

Both younger and older adults showed generalized learning across five consecutive days of training. Both groups showed a response time decrease of about 44 ms from Monday to Friday. It is likely that with a greater amount of training per day, there would be a faster decrease in response times to the center target. Yet we observed this response time decrease for both the compatible and the incompatible trials. This equivalent decrease in the two types of trials differs from the results of other studies that have found the effect of training to be beneficial largely for the incompatible trials. Ishigami and Klein (2010) found a decrease in interference due mainly to a decrease in the response time for the incongruent condition whereas the response time for the congruent condition was relatively stable across 10 days of training on the ANT task. Measures of brain activity in studies also found a stronger response conflict for older adults on incompatible trials than on compatible trials—reflected by the LRP effect, an index of selective response preparation (Zeef et al., 1996). It is not clear why practice affected compatible and incompatible trials similarly in the present study. However, the results in the present study are similar to the findings of Brown and Fera (1994, Experiment 3) in which practice effects were not observed when participants were given two blocks of practice sessions on the flanker task. A closer look at the data for Experiment 3 in Brown and Fera (2004) indicates that there was about a 20 ms decrease for both the incompatible and compatible conditions after a second block of practice. The present study demonstrates that training for five consecutive days improves the processing speed of information for both the compatible and incompatible trials.

One concern is that practice effects may influence performance differently depending on the flanker-target distance. However, in the present study, flanker-target distance was very small (< 1 deg) and was held constant between younger and older adults. The similar interference effects in younger and older adults in our study suggest that flankers were within the width of the attention spotlight in both groups.

Another possibility is that the usefulness of the flankers may influence the extent of any practice effect on response performance. Brown and Fera (1994) found that participants narrowed their focus of attention depending on the usefulness of the flankers; that is, if only one of two flankers was correlated with the correct response, it was more beneficial to narrow the focus of attention than when both flankers were correlated with the correct response. Perhaps we would then see a training effect on flanker interference, that is, showing reduced flanker interference across sessions if there was more incentive to narrow the focus of attention.[1]

[1] A one-to-one response mapping, where one response key is mapped to one letter and the other key is mapped to the other letter, is unlikely to influence our results. The one-to-one response mapping is similar to ANT tasks; participants press one key if the target arrow is pointing to the left and another key if the center arrow is pointing to the right. Studies using the ANT tasks do find age differences in interference (Rueda et al., 2005).

Overview and Implications

The present findings suggest that although training on a simple flanker task over five consecutive days benefits the overall efficiency of processing of information, training does not reduce the interference of distracter information for younger or for older adults. The benefit of the efficiency of processing information occurs not only for incompatible conditions, in which distracter information is different from target information, but also for compatible conditions, where distracter and target information is the same. This overall improvement may hinge on learning to quickly identify the four possible stimuli, or on learning the pacing of the trials—basically, on what has in the past been called “learning to learn” (see, e.g., Duncan, 1950).

The central finding of this thesis suggests that training on simple cognitive tasks can benefit the executive attention network of both younger and older adults. Although the total amount of training across five days is more than that used in other studies that found practice effects using the flanker task (Brown & Fera, 1994; Ishigami & Klein, 2010), it may be that the amount of practice during a single day was not enough to benefit interference. Future studies may want to examine what amount of practice within a single day is required for long-term benefits of training on the executive attention network to be seen. Perhaps, for example, more training is required on the first few days but long-term effects may be preserved with occasional training after the initial training phase.

Furthermore, future studies may also want to examine different types of training which may have differential benefits for younger and older adults. It has been found, for example, that older adults show a benefit in processing information when presented with cues that are more informative to the goal of the task (Jennings et al., 2007), a finding also consistent with the Brown and Fera (1994) results just considered. Other studies (e.g., Tang et al., 2007) have differentiated between tasks that involving repetitive trials of various cognitive tasks (e.g., Stroop tasks, flanker tasks) and tasks that involve training of the mind and body (e.g., meditation, mindfulness training). Training on both types of tasks has been shown to be beneficial to the executive attention network, but training on the latter type of task may improve executive attention for both groups with less effort (Rueda et al., 2005; Tang et al., 2007). Intriguingly, consistent with Tang and Posner (2009), training may be most beneficial when the state of attention is "balanced"—when training is neither too effortful nor too effortless.

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Table 1

Mean response time (RT), difference score (RT of incompatible trials minus RT of compatible trials) and error rate (in percentage) for the compatible and incompatible conditions across five sessions, shown separately for younger and older adults. Standard errors are given in parentheses.

RT in ms (SE)		Session 1	Session 2	Session 3	Session 4	Session 5
Younger adults	compatible	553 (26.38)	512 (25.54)	505 (26.49)	509 (24.96)	509 (22.46)
	incompatible	587 (26.29)	548 (23.92)	543 (25.42)	543 (24.84)	543 (23.68)
Older adults	compatible	716 (25.30)	702 (24.50)	703 (25.41)	699 (23.94)	673 (21.54)
	incompatible	753 (25.21)	729 (22.94)	727 (24.38)	730 (23.83)	708 (22.71)
Difference Scores (RT Incompatible trials – RT Compatible trials) (SE)		**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Session 5**
Younger adults		34 (6.63)	36 (5.00)	38 (4.47)	34 (5.27)	34 (5.16)
Older adults		36 (6.36)	27 (4.78)	24 (4.29)	31 (5.05)	35 (4.95)
Mean % Error (SE)		**Session 1**	**Session 2**	**Session 3**	**Session 4**	**Session 5**
Younger adults	compatible	1.90 (.30)	1.68 (.33)	1.68 (.26)	1.45 (.34)	1.72 (.25)
	incompatible	3.17 (.53)	4.17 (.51)	3.31 (.48)	4.76 (.66)	4.03 (.65)
Older adults	compatible	0.54 (.29)	0.25 (.32)	0.67 (.25)	0.17 (.33)	0.25 (.24)
	incompatible	0.88 (.50)	0.38 (.49)	0.46 (.46)	0.38 (.63)	0.67 (.62)

Figure 1. On each trial, a fixation appeared for 1000 ms, followed by a blank for 1000 ms, and the flanker stimulus. The flanker stimulus was selected from one of four equally likely possibilities, two of which were compatible and two of which were incompatible. The flanker stimulus remained on the screen until the participant responded.

Figure 2. Mean response time (RT) in the compatible and incompatible conditions across five sessions for younger and older adults. The error bars represent the standard error of the mean for each point.

Figure 1

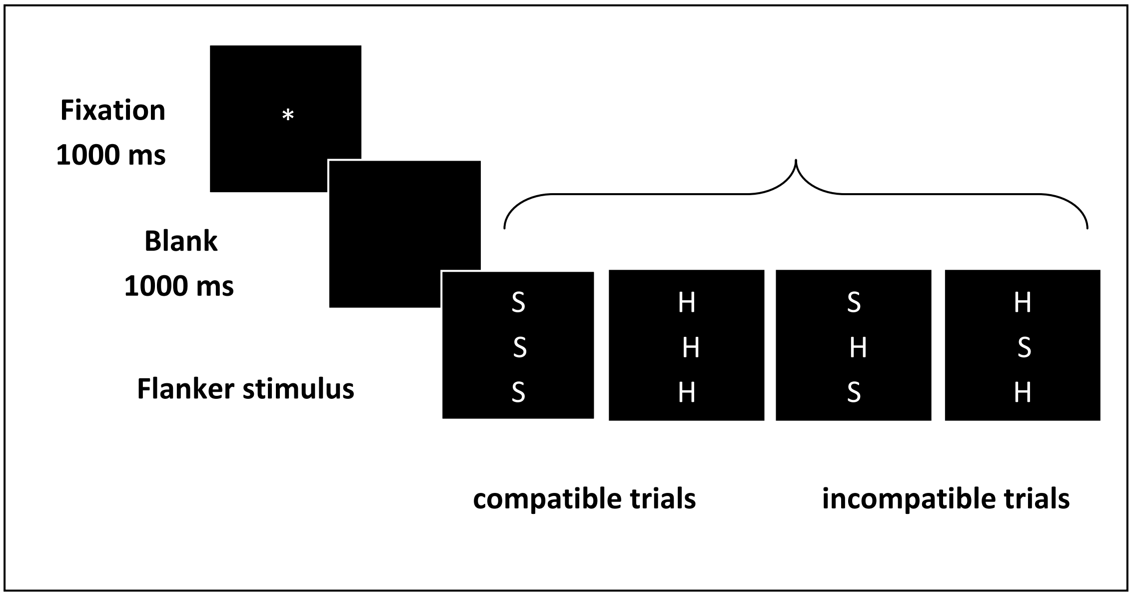
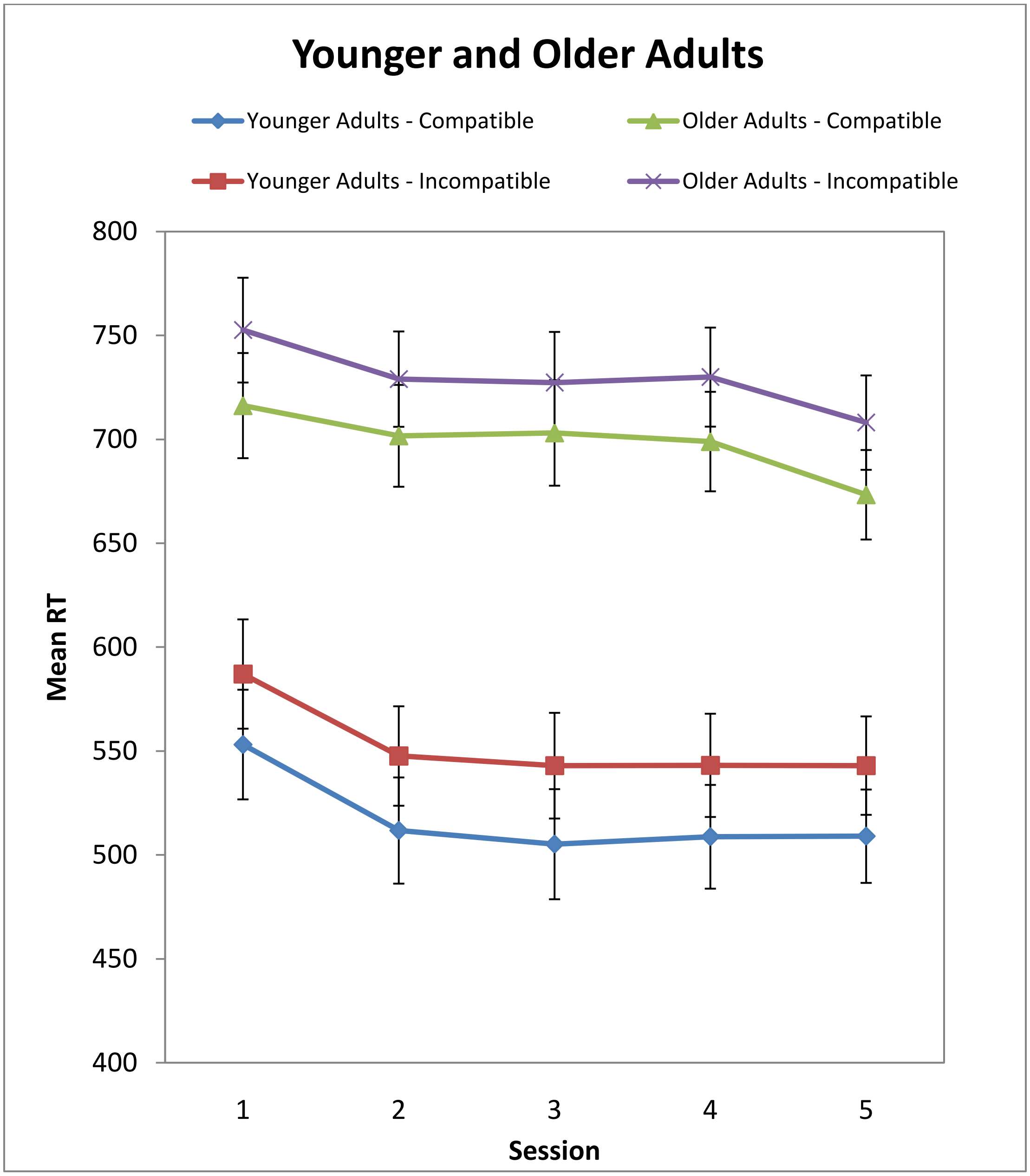

Fixation
1000 ms
*
Blank
1000 ms
Flanker stimulus
S
S
S
H
H
H
S
H
S
H
S
H
compatible trials
incompatible trials

Figure 2


Younger and Older Adults
Younger Adults - Compatible
Older Adults - Compatible
Younger Adults - Incompatible
Older Adults - Incompatible
800
750
700
650
600
550
500
450
400
Mean RT
1
2
3
4
5
Session