# A Study of Age Group Differences in Multiple Measures of Executive Functioning

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# ABSTRACT

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Recent empirical findings have shown difficulties in assessing age group differences in executive processes and their role in executive functioning. More specifically, inhibition is an executive control process whose role in executive functioning has been poorly defined. The purpose of the current study was to extend the findings of sequential action research by examining the processes that govern sequential behaviour (i.e., self-inhibition), and to relate these findings to other measures of executive functioning (Stroop task, Visual Span, Random Generation Task). We also investigated intraindividual variability and examined the correlations between intraindividual variability and level of performance in executive measures.

As hypothesized, individuals showed evidence of self-inhibition on the Sequential Action (SA) paradigm. Results on the other executive measures revealed that older adults performed significantly worse than younger adults, with modest intercorrelations between executive measures and the SA paradigm. This suggests that executive functioning is a multifaceted construct. Furthermore, these correlations were stronger for younger adults suggesting that executive functioning may be more differentiated in older adults. Older adults exhibited greater intraindividual variability on the SA paradigm. Intraindividual variability was correlated across only some measures. The pattern of correlations underscores the need to consider both intraindividual variability and level of performance when examining age group differences in executive functioning.

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# Dedication

To my husband whose ability to laugh and strength to persevere continues to inspire me.

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# Introduction

Researchers have documented a wide array of adult age differences in cognitive functioning over the last few decades. Cognitive functioning in older adults is more complex than most individuals would assume. Despite common assumptions, cognitive abilities do not all decline linearly in adulthood. While some abilities do show age related decline, others remain stable or show positive age differences up until the 60s (e.g., Hertzog & Schaie, 1986; Salthouse, 2004; Schaie, 1996). For example, across the lifespan there is an increase in acquisition of knowledge (e.g., higher vocabulary test scores in older adults) as well as a negative age trend in measures of speed, reasoning, and memory (e.g., reduced short term memory in older adults; Salthouse, 2004).

Major theories of cognitive aging have offered single-factor explanations to account for specific patterns of stability, improvement, and decline. This is in contrast to more local theories of cognitive aging that account for specific phenomena (e.g., visual search). One such single-factor theory is the Common Cause hypothesis which states that generalized central nervous system (CNS) degeneration compromises cognitive performance (Christensen, Mackinnon, Korten, & Jorm, 2001). A related single-factor theory argues that reduced processing speed is the direct consequence of age-related biological changes that compromise cognitive performance (Salthouse, 1996) while others postulate that diminished inhibitory mechanisms are responsible for age associated cognitive decline (Hasher & Zacks, 1988). The majority of evidence for such hypotheses is cognitive in nature. Convergent with such evidence, neuropsychological and neurobiological evidence has led to the suggestion that age-related declines in memory may be due to a subclinical and selective decline in executive function (Bellgrove, Heste,

& Garavan, 2004; Moscovitch & Winocur, 1992; Troyer, Graves, & Cullum, 1994). Other researchers suggest non-cognitive factors that account for age associated cognitive decline. For example, Schneider and Pichora-Fuller (2000) propose that it is the covariation of sensory and cognitive function that represents widespread CNS atrophy or degeneration. In contrast, Hultsch et al. (2000) suggest that intraindividual variability is representative of CNS atrophy in older adults and clinical populations. Although single-factor theories are global in their explanatory scope, they are not necessarily mutually exclusive. For example, reduced sensory acuity could co-exist with less efficient inhibitory processes, or reduced attentional capacity.

The present study is focused on one theory to better understand how it contributes to the phenomenon of cognitive aging. We chose to investigate executive functioning because of its potential to explain cognitive functioning in older adults and to further integrate cognitive and neurobiological explanations of cognitive aging. From a cognitive standpoint, executive functioning incorporates many component processes (e.g., inhibition, working memory) that are hypothesized to be central to cognitive functioning in older adults (e.g., Baddeley, 1986, Hasher & Zacks, 1988). An understanding of how these processes interact in older and younger adults may inform models of age associated cognitive decline, more generally. From a neurobiological perspective, executive functioning has been associated with the frontal lobes, an area in which impairment in this region is thought to be a central cause of age associated cognitive decline (Stuss & Alexander, 2000). A more thorough understanding of specific frontal lobe processes and how they interact among each other and with chronological age would contribute to the evidence for frontal lobe compromise as an explanation of cognitive aging.

In the present chapter, work on age differences in executive functioning and its component cognitive processes will be reviewed. Of particular concern is the question of how many cognitive processes are subsumed within the executive functioning framework. The subsequent section will focus on sequential behaviour as an example of executive functioning. The relevant experimental and neuropsychological literature on sequential performance will be reviewed. Within the discussion of sequential performance, inhibitory processes and age-related changes therein will be discussed, given their role in sequential performance. Lastly, the issue of intraindividual variability will be discussed as an additional dimension of measurement that has been related to frontal lobe status and executive functioning.

*Executive Functioning, Associated Cognitive Processes and Development*

Executive functioning as a higher order function is loosely comparable to running a country. An individual who runs a country may have no particular specialty but shows a diffuse ability to manage the country from economic, social, and military vantage points. If we consider the demands of such a prestigious job, one might imagine that planning, decision making, and self regulation are key abilities needed to run a country. Likewise, there is broad agreement that executive functioning includes abilities like self-regulation, sequencing of behaviour, flexibility, response inhibition, planning, and organizing behaviour (Eslinger, 1996).

Younger and older adults perform tasks that require these executive functions every day. For example, successfully driving a car requires coordination of a number of tasks. These tasks include cognitive abilities like attending to the relevant stimuli in the environment, ensuring the car is functioning safely, and following signage. There is considerable research demonstrating age associated cognitive decline in some of these executive functions. For example, Cepeda, Kramer, and Gonzalez de Sather (2001) conducted a study to examine executive control processes (i.e. the ability to flexibly alternate between two different tasks; task switching) across the lifespan. Participants performed two different tasks: deciding whether the number 1 or the number 3 was presented on the computer screen, and deciding whether a single number or three numbers were presented on the computer screen. Subjects either performed these tasks repeatedly (non-switch block) or switched from one task to the other within the same block. Switch costs were calculated by subtracting the RT from the non-switch trial from the RT from the switch trial. A U shaped function was observed for switch costs with larger costs found for young children and older adults. Cepeda et al. (2001) demonstrated that older adults exhibited a decline in task switching, as compared with younger adults, lending support to the notion that executive processes decline with age.

Documented age-related decline in inhibitory functioning can also be considered convergent evidence of executive functioning decline. For example, McDowd and Filion (1992) examined the efficiency with which younger and older adults allocate attention to relevant stimuli and inhibit attention to irrelevant stimuli. Participants were instructed to either attend to or ignore a series of innocuous tones, and the orienting response elicited by each tone was measured by skin conductance. The results demonstrated that younger adults instructed to ignore the tones habituated more quickly than did those instructed to attend to the tones. Conversely, older adults exhibited non-differential orienting across the two conditions suggesting an age related deficit in the ability to inhibit attention to irrelevant stimuli.

Similarly, findings from the neuropsychological literature examining executive performance have shown age associated decline in executive functioning. For example, the Stroop task has shown age associated decline in performance (e.g., Houx, Jolles, & Vreeling, 1993 but see also Rogers & Fisk, 1991) which has been interpreted as evidence of reduced inhibitory control in older adults (for review see Kramer, Humphrey, Larish, Logan, & Strayer, 1994). Because neuropsychological tests of executive functions were developed to detect significant performance deficits in patients with frontal lesions, not all tests are age-sensitive in healthy samples (for review see Bryan & Luszcz, 2000). For example, studies using the Wisconsin Card Sorting Test (WCST) as a measure of executive functioning have not yielded consistent age differences in performance (Bryan & Luszcz, 2000).

While there is experimental and neuropsychological support demonstrating age differences in executive control processes (e.g., task switching, inhibitory control), it is important to understand whether these cognitive abilities are distinct abilities. This has been a long-standing debate in the literature (e.g., Rabbitt & Lowe, 2000; Salthouse, Atkinson, Berish, 2003; Stuss, & Alexander, 2000). It is of particular importance to examine executive control processes in order to further develop theories of cognitive aging given the fact that the frontal lobes are implicated in the aging process (e.g., Stuss & Alexander, 2000), and that executive functioning has been deemed a largely frontal construct (e.g., Rabbitt & Lowe, 2000).

The link between the frontal lobes and executive functioning, irrespective of aging, can be traced back to neuropsychological findings indicating that individuals suffering from frontal damage have a distinct set of cognitive disturbances (e.g., inability to perform complex sequential behaviour). Again, there is considerable debate as to what this distinct set of cognitive disturbances is (for review see West, 1996). One solution to the debate is to conceptualize these disturbances under the umbrella term, executive functioning (Stuss & Alexander, 2000). Neuropsychological tests assessing frontal lobe deficits have demonstrated that individuals with frontal damage perform poorly on tests of executive functioning (West, 1996).

Taken together, the constructs of executive functioning and frontal lobe status can then be empirically linked to cognitive aging phenomena. Evidence of a selective, age-related decrease in performance on neuropsychological measures of frontal lobe functioning has given rise to the frontal lobe hypothesis of aging (e.g., West, 1996). Broadly stated, this hypothesis claims that age associated frontal lobe deterioration is largely responsible for age-associated decline in cognitive functioning (Moscovitch & Winocur, 1995). There is both support (e.g., West, 1996) and refuting evidence (Band, Ridderinkhof, & Segalowitz, 2001) for the extent to which the frontal lobe hypothesis provides a parsimonious explanation for cognitive aging phenomena (for review see Greenwood, 2000).

*Assessing executive functioning in older adults.* Understanding executive functioning within the context of aging has been a complicated endeavour. Neuropsychological tests assessing executive function are continually being devised and reevaluated due to the heterogeneity of executive functions, and the complexity of evaluating these functions (Robbins et al., 1998), as well as the poor reliability and validity of existing tests (for review see Rabbitt, 2003). The difficulty in assessing executive functioning is directly related to its construct validity (Salthouse et al., 2003) and the problems establishing if there is a global age-associated decline in executive functioning, let alone any age-related differences in the abilities therein (Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000).

Neuropsychological tests of executive functioning were originally developed to assess decline in clinical populations (i.e., patients with frontal lesions). Because of the origin of their development, it is likely a complex endeavour to use them to assess normative age associated cognitive decline. Bryan and Luszcz (2000) recently cautioned that although neuropsychological tests are often used to detect adult age differences in executive functions, these tests may be of less utility in assessing sub-clinical executive patterns compared to their use with clinical populations. Creating tests of executive functioning that are sensitive to clinical dysfunction as well as age differences warrants careful consideration of both the cognitive aging and neuropsychological literature.

To examine age differences in executive functioning, one must ascertain that the tests adequately tax the resources of the normative aging population. This can be difficult because once frontal tests cease to be novel, they often fail to tax the resources of even patient populations (Burgess, 1998). More specifically, if a sudden discovery of an appropriate strategy is made, putative measures of executive functions are likely to show low reliability (Lowe & Rabbitt, 1998). One way of addressing this issue is to consider additional dimensions of performance. Typically, one examines level of performance to determine group differences on a test of interest. Recent studies suggest that intraindividual variability in cognitive performance can differentiate clinical populations from normative samples (Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000), as well as older adults from younger adults (S.-C. Li & Lindenberger, 1999). That is, examining the extent to which an individual changes or remains stable across short time periods may provide unique information on the cognitive process being measured. More specifically, independent of mean level of performance, older adults tend to exhibit greater intraindividual variability in cognitive performance (for review see Hultsch & MacDonald, 2004). This measurement of intraindividual variability could prove impervious to the methodological limitations associated with the novelty of an executive task given that the discovery of a successful solution strategy does not necessarily impact an individual's variability on the task. Given that performance accuracy on executive tests can be insensitive to age differences in level of performance (Bryan & Luszcz, 2000), intraindividual variability analysis could prove to be more sensitive using the same tasks.

The analysis of intraindividual variability may be of further use in the present investigation because increased intraindividual variability is also associated with impaired frontal functioning (e.g., Stuss, Murphy, Binns, & Alexander, 2003; Stuss, Stethem, Hugenholtz, Picton, Pivik, & Richard, 1989). The association between frontal functioning and intraindividual variability points to the possibility of impaired attentional control, memory lapses or reduced inhibition as sources of increased intraindividual variability. By measuring intraindividual variability in executive functioning, one can obtain a 'frontal' measure of functioning that is independent of the executive test. That is, the measurement of intraindividual variability on a test of executive functioning provides an additional indicator of frontal functioning independent of any methodological constraints associated with level of performance on executive functioning. Additionally, a careful examination of intercorrelations from both the intraindividual variability and level of performance measures across the executive tests could provide additional insight into the construct validity and brain region localization of executive functioning, and the age differences therein.

*Intraindividual Variability in Cognitive Performance*

The investigation of intraindividual variability in cognitive performance has been examined relatively infrequently in the aging literature. Intraindividual variability refers to the characteristics and behaviours of an individual that change or remain stable over time. Nesselroade (1991) distinguishes between two types of within-person change. Intraindividual change refers to change that is durable and systematic, whereas intraindividual variability refers to change that is transient (e.g., changes in state, or cyclical fluctuations). For example, consider an individual who plays tennis. Initially, the person hits many successful serves but fails to return the ball to his opponent. Over the course of the tennis match, the individual's ability to serve and return the ball to his opponent ranges from an advanced to a beginner level. This individual would be considered to have exhibited intraindividual variability throughout the match independent of his actual score in the games. This type of inconsistency has also been observed in various cognitive contexts (e.g., Segalowitz & Segalowitz, 1993) and has prompted researchers to examine intraindividual variability in cognition as it relates to cognitive aging theories (for review, see Hultsch & MacDonald, 2004).

The investigation of intraindividual variability requires the dissociation of systematic within-person variability (e.g., practice and material effects) from changes that are lawful but transient. It is also important to demonstrate that the magnitude of intraindividual variability is not merely a statistical artifact of individual differences in mean performance. Preliminary evidence indicates that there is substantial intraindividual variability in cognitive performance that can be measured reliably, independent of individual differences in mean performance and systematic effects associated with materials, practice, or other influences (for review see Hultsch & MacDonald, 2004).

Because most research in cognitive psychology and neuropsychology has focused on average differences in level of performance, there is limited information on group differences in intraindividual variability. However, the existing data support the notion that there is greater intraindividual variability for some types of persons on some tasks. For example, several studies have shown that intraindividual variability across trials on RT tasks increases with age (e.g., Anstey, 1999; Salthouse, 1993) although there is disagreement as to whether the increase in intraindividual variability can be accounted for by group differences in mean level of performance (e.g., Salthouse, 1993). In addition to inconsistency across trials within a session, intraindividual variability can be observed across multiple testing occasions. Li, Aggen, Nesselroade, and Baltes (2001) examined intraindividual variability for a set of memory (i.e., digit memory span, memory for short text and spatial recognition) and sensorimotor (3 walking tasks) variables across 13 bi-weekly sessions in a sample of 24 older adults. They found that intraindividual variability in older adults' sensorimotor performance was substantial and positively correlated with age. It was also negatively correlated with level of performance on sensorimotor and memory measuring indicating that the worse an individual performed on these measures, the more variable they were across sessions. This finding is consistent with Hultsch et al. (2000) that indicated that the worse an individual performed on a given task, the higher their intraindividual variability was. Notably, in Hultsch et al. (2000) intraindividual variability was calculated independent of level of performance and yet the correlation between level of performance and intraindividual variability was still maintained.

Neuropsychologists have commonly observed that patients with neurological disorders or injuries show both impaired levels of performance as well as inconsistency of their performance over time (Hultsch & MacDonald, 2004). Several studies have suggested that greater intraindividual variability may be observed in clinical populations including persons with traumatic brain injury (Bleiberg, Garmoe, Halpern, Reeves, & Nadler, 1997), dementia (Hultsch et al., 2000; Murtha, Cismaru, Waechter, et al., 2002), and Chronic Fatigue Syndrome (Fuentes et al., 2001). Intraindividual variability in performance may be particularly significant in the assessment of individuals whose disorders are subclinical or not easily definable (e.g., Hultsch et al., 2000; Stuss, Pogue, Buckle, & Bondar, 1994). These studies support the notion that intraindividual variability may be a behavioural indicator of compromised neurological mechanisms.

More specifically, studies examining intraindividual variability have suggested frontal involvement as a key element involved in the central nervous system compromise which manifests in greater intraindividual variability in performance. Stuss and colleagues have suggested that lesion location is a central factor relating to greater intraindividual variability in performance among brain-damaged individuals (Stuss et al., 1989, Stuss et al., 1994), and particularly damage in the frontal lobes (Stuss, Murphy, & Binns, 1999). Murtha et al. (2002) examined whether increased intraindividual variability in performance is a function of frontal lobe pathology. They examined intraindividual variability for a Stroop test and reaction time (RT) measures across five weekly sessions in samples of eight patients with dementia of the Alzheimer type (DAT), five patients with frontal lobe dementia (FLD), compared with 10 elderly normal controls. Both measures contained three subtests varying in the degree of complexity. Overall, the patients with FLD showed greater inconsistency in performance compared to individuals diagnosed with DAT. The varying degree of complexity had no significant effect in the Stroop test however; it did significantly affect the results of the RT measures. Greater intraindividual variability in performance was manifested only in the more attentionally demanding RT subtests (Choice Reaction Time vs. Simple Reaction Time). While the frontal region likely plays a role in increased intraindividual variability in performance, it is also important to consider the tasks in which intraindividual variability is measured. The research is equivocal as to whether the group differences are more pronounced for complex as opposed to simple tasks.

The findings in the literature on intraindividual variability suggest both age differences in variability as well as differences between clinical and normative individuals independent of mean level of performance (Hultsch et al., 2000; S-C. Li & Lindenberger, 1999). In addition to this, the frontal lobes are clearly important to consider when examining age group differences in intraindividual variability given the hypothesis that frontal lobe pathology is associated with increased levels of variability.

Using a functional neuroimaging paradigm, Bellgrove, Hester & Garavan (2004) found significant associations between brain activations in the frontal regions and response variability suggesting that frontal lobe activity could relate to executive or inhibitory processes.

Based on this hypothesis, increased intraindividual variability in older adults may indicate frontal lobe compromise which would lend support to the executive functioning hypothesis of cognitive aging. That is, the assumption that executive functioning (or frontal functioning) is largely responsible for age associated cognitive decline would coincide with findings of increased intraindividual variability in older adults. Because the measurement of intraindividual variability in performance is a relatively complex endeavour, more studies examining age group differences in variability are warranted, using multiple tests varying in complexity, in order to better construct theories of cognitive aging as a whole, and the role of executive functioning therein.

To examine intraindividual variability, a minimum of three occasions is necessary in which the same test is administered. An analysis of intraindividual variability is not possible on most standard neuropsychological tests because they are developed for quick and efficient administration in clinical institutions, and have large practice effects (Miyake et al., 2000). Conversely, experimental paradigms that examine executive functioning typically do not have these inherent constraints.

One such paradigm was developed by K.Z.H. Li, Lindenberger, Rünger, and Frensch (2000) to investigate the role of inhibition in the regulation of sequential action. This sequential action (SA) paradigm yields a large series of data points during one session (approximately 300 reaction time points), and it is amenable to repeated administrations. This paradigm is a useful test of executive functioning for a number of reasons. Firstly, sequential performance is a global behaviour that encompasses cognitive processes such as inhibition, self-regulation, and flexibility, which are known executive control processes. Secondly, the investigation of sequential performance can potentially bridge the neuropsychological (e.g., Humphreys & Forde, 1998) and cognitive (e.g., Houghton & Tipper, 1994) literatures by using everyday action sequences, which are often evaluated in neuropsychological research. The incorporation of everyday tasks increases the ecological validity of the paradigm while preserving the internal validity of the task.

*Measuring Sequential Behaviour*

Everyday behaviour often consists of action sequences, rather than actions in isolation (Miller, Galanter, & Pribram, 1960). To understand everyday behaviour, one must understand the cognitive processes that allow individuals to carry out action sequences that comprise their everyday behaviour. It is generally agreed upon that these cognitive processes represent 'high-level' control of human behaviour associated with the frontal lobes (Humphreys & Forde, 1998). Theorists have tried to explain these executive processes which underlie everyday behaviour by postulating cognitive models.

Norman and Shallice (1986) explain how one executes routine tasks with two systems; the Contention Scheduling System (CSS) and the Supervisory Attentional System (SAS). They suggested that the CSS stores schemas for routine tasks, and that when a stimulus activates a particular schema above its threshold, that schema remains active until goal attainment occurs, or until it is inhibited by competing schemas. The second system, the SAS, is thought to be responsible for the control of non-routine, more complex actions that require "higher order" cognitive control. This contention scheduling model has been used to explain sequential action within a naturalistic domain although the authors acknowledge that the model is too constrained to account for all aspects of sequential behaviour (Cooper & Shallice, 2000). Other theorists have postulated models that link the SAS with the CSS as a system that reflects the operation of knowledge sources at different levels of abstraction. For example, Grafman (1995) argued that sequential everyday behaviours depend on the activity of stored memories that are organized into "Structured Event Complexes" and "Managerial Knowledge Units". Structured Event Complexes are considered the more primitive units that store a sequence of actions. Managerial Knowledge Units are comprised of associated Structured Event Complexes that combine to form a sequence of actions for "higher level" processing. According to Grafman's proposal, Norman and Shallice's SAS is not distinct from the CSS, it is a system that is guided by specific schema from the CSS that allows it to regulate actions in underspecified conditions.

While both of these models provide a general framework to explain everyday sequential behaviour more globally, other researchers have focused on the underlying cognitive processes associated with sequential behaviour. For example, Humphreys and Forde (1998) reported the results of an amnestic patient who was able to perform routine actions in the correct sequential order, implying that intact memory processes may not be necessary. Normative samples of adults can be susceptible to errors in action sequences such as action slips (omitting an intended action), perseverations (repeating a previously completed action), and anticipation errors (carrying out an action too early in a sequence) (e.g., Li et al., 2000; Reason, 1984).

There has been a longstanding assumption that the generation of sequential actions requires the parallel activation of all actions belonging to the sequence before their execution (Estes, 1972; Lashley, 1951). Accordingly, because all actions are highly active during sequential behaviour, there must be additional mechanisms of selection to ensure that a given action is carried out in the correct serial order.

These assumptions are reflected in recent neural network models of sequential-action regulation (e.g., Houghton, 1990; Houghton & Tipper, 1996). Houghton (1990) postulated a "Competitive Queueing" (CQ) framework that builds on previous models of sequential behaviour. The CQ architecture delineates two processes, that of response preparation or parallel activation of item nodes, and response selection. Response selection occurs by activating the competitive filter. Central to the operation of the competitive filter is the process of inhibition. First, the currently relevant action inhibits all competing actions. Next the process of self-inhibition occurs in which a just completed action undergoes inhibition to make the next action the most highly activated thereby propelling the sequence forward. While the CQ framework has only been postulated as a potential explanation of the control processes that govern sequential behaviour, preliminary evidence with lower animals supports the CQ architecture (Houghton & Tipper, 1996).

Subsequently, Houghton and Tipper (1994) outlined a model of selective attention that is similar to the CQ models (with the exception of the role of inhibition). Their model proposes that in selecting one input from a series of competing inputs, individuals must have in mind a partial description of the to-be attended item that distinguishes it from others. When there is a match between the description of the item and an input, there is activation. When inputs fail to match the target, they are perceived as distractors and therefore inhibited. The resulting decrease in the level of activation of distractors does not fall below the background level of activation. The combined inhibitory and excitatory backgrounds facilitate the binding of response schemas to properties of selected objects. The role of inhibition in the Houghton and Tipper (HT) model (1994) is generally directed at distractors, whereas in CQ models (1990), inhibition is theorized to act on selected items or targets after they have been output. The conclusion drawn from the two models is that inhibition is an integral component in the control of action. In both models, the process of inhibition not only enables the selective action towards one object, but also controls the sequential flow of action. A prediction from such models is that completed actions are less available (i.e., below baseline activation levels) due to inhibition.

Houghton's assumptions have been subsequently explored in the context of spelling (Houghton, Glasspool, & Shallice, 1994), language production (Dell, Burger & Svec, 1997) mental arithmetic (Arbuthnott, 1996), and serial recall (Maylor & Hensen, 2000). In general, this literature supports the assumption of inhibition by showing that intrusion errors are more frequently committed in the future direction than the past thereby illustrating the successful inhibition of a recently undergone action.

Li et al. (2000) explored these assumptions by studying sequential performance of an overlearned sequence. Participants learned a temporal sequence of seven stimulus categories and then monitored for an instance of them during successive displays. All of the displays were instances of these categories, presented in pseudo-random order. On each trial, participants monitored for an instance of the first category (target), pressed a key on a computer keyboard, and so on for all seven categories. The target shifted throughout the paradigm as participants pressed a key when they saw an instance of the first category through to the seventh category. An analysis of the intrusion errors revealed that fewer intrusion errors were made at near serial positions to the target than at further serial positions from the target. For example, when monitoring for an instance of the second category, participants were more likely to err by responding to an instance of the seventh category than by responding to an instance of the third category. Li et al. (2000) claimed that this represented a gradient of lateral inhibition in which the closer the distractor was in temporal order to the target, the stronger the inhibition was. In addition, more errors were made on anticipated targets than on targets already completed. This was interpreted as representing the process of self-inhibition, in which the just completed action undergoes inhibition to make the next action the most highly activated (reviewed in the CQ architecture).

Subsequent studies suggest that lateral and self-inhibition are dissociable processes in that the former inhibits all distractors that are temporally close to the target, and the latter inhibits a just completed action. Chow (2002) used a similar paradigm to Li et al. (2000) in which the sequence of seven stimulus categories learnt were animals ordered according to size. The results of Chow (2002) were consistent in terms of self-inhibition in that there were more errors on anticipated targets than on targets already completed. However, in Chow (2002) there was no evidence of lateral inhibition. The results showed more intrusion errors at near serial positions to the target and fewer intrusion errors at further serial positions from the target. Post-hoc analyses suggest that this pattern resulted from participants grouping or chunking the series of items.

Rünger (2002) re-analyzed the Li et al. (2000) data and suggested that an additional cause of the reported U-shaped error function was that of visual similarity between specific goal categories (e.g., letters vs. numbers). Visual similarity might also explain the discrepancy between the earlier U-shaped error function and Chow's (2002) inverted U. Notably, the change from arbitrarily ordered unrelated categories (Li et al., 2000) to a naturalistic sequence (Chow, 2002) may have resulted in greater confusability between proximal distractors. Considered together, these findings suggest that lateral inhibition and self-inhibition are distinct, dissociable constructs. Additionally, this reanalysis suggests that the U-shaped error function may not be representative of lateral inhibition. Furthermore, the literature suggests that age differences in sequential performance may be worthwhile to examine given that inhibition may be central to executive functioning in older adults.

*Neuropsychological Disorders of Sequential Behaviour*

Complementary evidence is observed in the neuropsychological literature that examines actual disorders of sequential behaviour (Humphreys & Forde, 1998; Schwartz, Mayer, Fitzpatrick, DeSalme, & Montgomery, 1993) in frontally compromised patients. Disorders of sequential behaviour are most often examined by looking at naturalistic action or sequences of movements that are well established through practice (e.g., eating with a fork and knife). The neuropsychological literature has afforded minimal attention to the investigation of naturalistic action disorders because they are difficult to assess in a controlled clinical setting. Research has not focused on sub-clinical performance in naturalistic action because naturalistic action disorders are unlikely to come to the attention of investigators unless the magnitude of the disorder is large, involving damage to the cerebral structures (e.g., late stage Alzheimer's disease; severe traumatic brain injury; Schwartz & Buxbaum, 1997). Using naturalistic action to investigate age differences in sequential performance may shed light on the cognitive processes that are necessary for clinical, sub-clinical, and healthy older adults to perform naturalistic sequences.

Humphreys and Forde (1998) assessed the performance of two patients with Action Disorganisation Syndrome, and two control patients matched for short-term, and long-term episodic memory performance. Patients with Action Disorganisation Syndrome were identified as individuals who had lesions to the frontal lobe and subsequent impairment on the performance of everyday tasks similar to similarly identified patients in Schwartz et al. (1995). This included difficulty in both generating the correct component actions to a task, and knowing the correct temporal sequence. By comparing patients with Action Disorganisation Syndrome to patients who had deficits on cognitive abilities that may represent some component skills necessary for successful performance on everyday tasks, the authors identified specific components that contribute to Action Disorganisation Syndrome (in line with previous research). The first experiment used 45 undergraduate students to generate scripts for nine action tasks (e.g., writing and posting a letter, wrapping a gift, smoking a cigarette, and shaving your face). Core action components for each task were identified by 80% of the participants. For example, in order to prepare cereal, 80% of the participants endorsed pouring cereal into the bowl, pouring milk into the bowl, and eating the cereal with the spoon. These action components were then used to compose the scripts constructed for testing patient populations.

In the next two experiments, patients were placed in front of a table and asked to perform a particular task from one of the scripts generated in the first experiment. Performance was videotaped for later analysis. The findings indicated that the Action Disorganisation Syndrome patients were more impaired than the controls when carrying out everyday tasks as indicated by the number of errors made on each task. This is indicative of other control processes besides memory being involved in carrying out everyday actions.

In subsequent experiments, Action Disorganisation Syndrome patients demonstrated deficits in their ability to generate action scripts orally, and to order the basic component actions in the scripts. The authors suggest that these patients have a disorder of action schema, and postulate different ways in which each patient's disorder or action schema breaks down. Humphreys and Forde (1998) suggest that the perseverative errors could reflect a deficit in automatic rebound inhibition. This is consistent with connectionist models (e.g., Houghton, 1990, Houghton & Tipper, 1996) in which inhibition is thought to prevent the repetition of previous actions. Once a sub-action has been performed, the patient does not automatically inhibit that action in order to perform the rest of the task in the correct sequential order. This is akin to the concept of self-inhibition which has been postulated to propel sequential behaviour forward in cognitive paradigms (e.g., Li et al., 2000).

Taken together, these findings indicate that the evaluation of a complex process (i.e., sequential behaviour) is a multi-layered endeavour. The examination of sequential behaviour requires careful consideration of the component processes required to execute sequential behaviour. The literature thus far seems to point to inhibition as a key process required to complete sequential tasks.

*Adult Age Differences in Inhibition*

Inhibition is not only important to consider in executive functioning, but it also plays a central role in general cognitive processes. Recent years have witnessed a focus on inhibitory processes in cognition (e.g., Dempster, 1992), as well as age differences in inhibitory functioning (Engle, Conway, Tuholski, & Shisler1995; Hasher & Zacks, 1988; Kramer, Humphrey & Larish, 1994; McDowd, Oseas-Kreger, & Filion, 1995).

Early evidence suggesting that older adults are susceptible to interference in cognitive functioning (e.g., Rabbitt, 1965) led Hasher and Zacks (1988) to propose the inhibition deficit hypothesis of cognitive aging. They postulated that the documented age related decline in cognition is likely due to a decline in the efficiency of the inhibitory mechanisms. Although the inhibition deficit hypothesis was originally proposed to explain age differences in working memory, it was generalized to account for age differences in cognition because working memory was thought to be an index of general capacity available for mental work (Zacks & Hasher, 1997).

Hasher and Zacks (1988) identified two inhibitory mechanisms that were responsible for restricting processing at both encoding and retrieval of goal-relevant information. The first mechanism is required to prevent goal-irrelevant information from entering working memory thereby interfering with the processing of goal-relevant information. The second mechanism prevents irrelevant information from remaining in working memory when it is no longer relevant to the current goal. Hasher, Zacks and May (1999) have recently elaborated the hypothesis by identifying the three processes that are required in order to achieve these tasks. Firstly, inhibition controls the *access* to working memory by preventing extraneous information from entering working memory, second, and *deleting* the activation of goals that are no longer relevant. Lastly, inhibition functions as a *restraining* mechanism whereby it prevents prepotent candidates for response from controlling thought and action. Taken together, the inhibitory deficit hypothesis suggests that older adults have less inhibitory control over the current contents of their working memory than younger adults. This results in a cluttered working memory that is vulnerable to any dominant response tendency thereby accounting for compromised performance on cognitive tasks.

The literature reveals mixed evidence for the inhibitory deficit hypothesis (Kramer et al., 1994; Maylor, Schlaghecken & Watson, 2005). For example, Maylor and Hensen (2000) investigated age differences in response suppression whereby once an action has been performed, it is then inhibited temporarily and hence unlikely to be performed again in the immediate future. They used a serial recall paradigm in which participants were asked to recall lists of letters in the correct order. Half of the lists contained repeated items while the other half were control lists. Both younger and older participants exhibited poor recall of repeated items when compared with control items. This finding implies intact inhibitory processes in older adults and calls into question the inhibition deficit hypothesis.

While the literature on sequential behaviour does not support or refute the inhibitory deficit hypothesis, it does have implications that may shed more light on the theory of inhibition. For example, the processes of self-inhibition and lateral inhibition (as defined in Li et al., 2000) as measured in sequential action regulation paradigms imply that the deletion function may have dissociable sub-components.

Because inhibition is such a broad construct, there is question as to whether normative aging impairs all of the types and levels of inhibitory mechanisms. More specifically, if we have overextended the use of the term inhibition, then perhaps a finer grained analysis of specific types of inhibition (e.g., self-inhibition and lateral inhibition) in different contexts is required to elucidate age differences in the specific inhibitory mechanisms. Furthermore, because the inhibitory deficit hypothesis is contingent upon an aging brain, whether or not inhibition depends on the integrity of the frontal lobes has been investigated and preliminary evidence suggests that intact inhibitory processes are directly correlated to the cognitive functioning of the frontal lobes (Kramer et al., 1994; Maylor, Schlaghecken & Watson, 2005). In order to further comment on the relationship between the frontal lobes and inhibition, more specific information about age differences in the various inhibitory functions is needed, as well as the examination of the intercorrelations between these inhibitory functions, measures of executive functioning and phenomena associated with the frontal lobes (i.e., intraindividual variability).

The study of sequential behaviour is important not only to help explain the relevant cognitive processes that govern sequential behaviour, but also to examine age differences in intraindividual variability and correlations with performance on executive functioning tasks. By analyzing level of performance and intraindividual variability in multiple measures of executive functioning we hope to provide a more conclusive assertion as to whether or not there is a global age-associated decline in executive functioning.

*The Present Study*

The purpose of this study is to examine age-related differences in executive functioning using both experimental and neuropsychological measures, and to evaluate the intercorrelations among mean level and intraindividual variability measures of performance. Because the frontal lobes have been strongly implicated in age-associated cognitive decline (Stuss & Alexander, 2000), we investigated cognitive functions that have been demonstrated to be associated with the frontal lobes. The equivocal findings about executive functioning in older adults combined with the assertion that it is associated with frontal functioning provided the impetus to examine different tests of executive functioning in older adults. To examine the relationship between intraindividual variability and frontal functioning, both level of performance and intraindividual variability were examined together. Lastly, because inhibition is central to models of executive functioning in the neuropsychological literature (e.g., Humphreys & Forde, 1998), and models of cognitive aging in the experimental aging literature (Hasher & Zacks, 1988), sequential performance seemed to be an appropriate behaviour to study.

We used a modification of the paradigm used in Li et al. (2000). Participants learned three separate sequences of routine everyday actions, with eight stimuli representing the steps that one would undergo to complete the action (from Humphreys & Forde, 1998). Participants then monitored for the stimuli during successive displays with an equal number of opportunities to make perseverative and anticipatory errors. In addition, several standard neuropsychological measures of executive function were administered to enable cross validation of the sequential action (SA) paradigm. This design offers greater ecological validity than that of Li et al. (2000) due to its use of everyday routines from Humphreys and Forde (1998). Using the same general procedure as in Li et al. (2000) allowed for the control of confounding variables such as distractor frequency, and provided a sufficient number of data points for use in intraindividual variability analyses.

*Expected Results*

The first section of results addresses the topic of sequential behaviour and its underlying mechanisms. Of particular interest was whether or not the present version of the SA paradigm would yield similar results to previous work (Chow, 2002; Li et al., 2000). Given that the present study more closely replicates that of Chow (2002) in its attempt to increase ecological validity, it was predicted that the data would reveal evidence for self-inhibition as defined in Li et al. (2000), in that more intrusion errors were expected in the forward direction than the backward.

The subsequent results chapter on executive functioning in performance levels and intraindividual variability addresses the issue of executive processes more generally by examining age differences on the neuropsychological measures of executive functioning and correlations between these measures and level of performance on the SA paradigm. One anticipated outcome is that the findings would reveal that performance on the SA paradigm is predictive of performance on executive task measures. This would substantiate Eslinger (1996) in that sequencing of behaviour, and response inhibition are all part of executive functioning. Conversely, the findings could reveal no correlation yet reveal age differences in the SA paradigm. This would suggest that Bryan and Luszcz (2000) are correct in their assertion that standard tests of executive functioning are not sensitive enough to detect bona fide age differences in functioning or that the SA paradigm is not a measure of executive functions.

Additionally, data from the SA paradigm and the neuropsychological measures are analyzed to consider whether significant age differences in intraindividual variability in performance (a frontal phenomenon) are observed. Of interest is whether intraindividual variability correlates with level of performance on the various tests of executive functioning for both younger and older adults. More specifically, does level of performance on the SA paradigm and on the neuropsychological executive task measures predict intraindividual variability on the SA paradigm? With respect to age differences in intraindividual variability, it was expected that older adults would be more variable than young adults, independent of their respective mean levels of performance. This would support the argument for compromised frontal functioning in old age. Lastly, it was expected that the correlations between intraindividual variability and level of performance on the SA paradigm and the neuropsychological measures would be significant. This would suggest a number of things. Firstly, significant correlations between level of performance on any of the aforementioned measures would suggest that all tasks are measuring a common construct, namely executive functioning. Age differences within these correlations would suggest that the construct may be valid for one age group and more diffuse a construct for the other age group. Next, if intraindividual variability correlated to level of performance we would replicate previous findings (e.g., Hultsch et al., 2000). Additionally, significant correlations could suggest that intraindividual variability and executive functioning (i.e. inhibitory processes) share some variance which is attributed to frontal functioning (e.g., Bellgrove et al., 2004). A lack of correlational evidence (in the presence of age differences) could be indicative of separate processes governing the neuropsychological tasks, the SA paradigm and intraindividual variability on these measures (see Miyake et al., 2000; Salthouse et al., 2003, for review of the unity and diversity of executive functions).

## Method

*Participants*

The sample consisted of 43 participants (23 younger adults, 20 older adults) recruited via newspaper advertisements and participants from previous studies at Concordia University[1]. The younger adults ranged in age from 19 to 36 years (M = 25.17, SD = 4.92), and the older adults ranged in age from 59 to 77 years (M = 66.60, SD = 5.59). Exclusion criteria for the two groups included the presence of any disease, health related disorder or use of medications that might alter cognitive status.

Participants provided demographic and self-reported health information before testing. In addition, participants were given the Digit Symbol subtest of the Wechsler Adult Intelligence Scale-III (Psychological Corporation, 1997a) as an indicator of cognitive status. Table 1 shows the age, education, self-reported health, Digit Symbol score, and gender of the participants as a function of group. There were no significant age group differences in self-rated health, $p = .12$ or years of education, $p = .37$. The older adults performed significantly worse on the Digit Symbol test than the younger adults, $F(1, 42) = 24.22$, $p = .00$, $\eta^2 = .37$. Because gender is often skewed in older populations (with women representing a higher percentage of the population), efforts were made to have a higher percentage of women in the younger group of adults as well. Within the older adults, 65.0% of the sample were female, and within the younger adults, 52.2% of the sample were female.

[1] One younger adult dropped out of the experiment after the first session. Subsequent analyses for session one include this participant, and all other analyses do not include this individual.

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Insert Table 1 about here

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*Measures*

*Experimental paradigm.* The SA paradigm is a computerized test of sequential action that is modeled after Li et al. (2000) in that it examines the ability to monitor for a given set of category exemplars in a sequential order. The SA paradigm investigates the same principles of sequential behaviour, using the same methodology with more ecologically valid stimuli. These stimuli are a series of three everyday tasks, consisting of eight sequential steps each. These tasks (wrapping a gift, writing and posting a letter, and smoking a cigarette) were used in the SA paradigm with the intention of reducing the memory component of the experiment compared to that of Li et al. (2000) in which individuals were instructed to memorize a randomly ordered set of abstract forms. In addition to reducing the memory component, having participants memorize the steps to complete an everyday task (naturalistic action) compared to memorizing a randomly determined order of abstract forms (as in Li et al., 2000) increases the ecological validity of examining sequential behaviour in younger and older adults because individuals typically perform these everyday tasks in their daily living. These tasks were taken from Humphreys and Forde (1998) who collected normative data (from college students) on the successive steps to a series of everyday tasks.

The SA paradigm was administered using a Macintosh G4, and programmed using SuperLab Pro 1.75 experimental generation software. Participants were required to monitor for the steps required to wrap a gift, write and post a letter, and smoke a cigarette. Each of the tasks has eight steps that are represented pictorially on the computer screen (see Appendix A). The pictures were taken using a Sony 1.6 megapixel camera with a 16X digital zoom. The pictures of the steps appear on a black screen in an 11X11cm square. Efforts were made to maximize the colour contrasts within the pictures, and to equate the colour contrasts across the pictures in the tasks. In addition, all pictorial representations of steps had minimal distractors (e.g., faces, scenery, objects that were not necessary to complete the steps) thus showing a clear representation of the given step.

The test was divided into three blocks. Each block represented a separate task; Block 1 = wrapping a gift (wrapping), Block 2 = writing and posting a letter (writing), and Block 3 = smoking a cigarette (smoking). Every block began with the instructions written on the screen in 24 point Times font (see Appendix B). The participant pushed the first key (key 1) on a SuperLab RB-610 response box in order to advance the screens. Once the testing began, the last key (key 6) on the response box was pushed in order to respond to stimuli. In any given block, participants monitored for the order of steps of the task that they memorized, with temporal distractors embedded within the sequences. For example, if a participant was supposed to be monitoring for step one of "wrapping", the appearance of step three of "wrapping" would be a distractor because it is not the correct step within the task that the participant was required to respond to.

Each block contained 42 fixed sequences, 14 of which had 15 stimuli, 14 had 16 stimuli, and 14 of which had 17 stimuli (see Appendix C). Each sequence contained the eight target steps, as well as between seven to nine distractors, depending on the length of the sequence. A fixed sequence had a random distribution of between zero and three distractors between the target steps. These distractors were classified in positive and negative lag terms for the purposes of analyses. The sequences facilitated the opportunity for both anticipatory and perseveratory errors. The three blocks (of 42 sequences) were each counterbalanced to ensure an equal number of opportunities to make anticipatory and perseveratory errors (see Appendix D).

To reduce the probability of practice effects associated with learning the structure of the sequences, the "wrapping and "smoking" blocks consisted of two independent counterbalancing orders using the aforementioned constraints. Because it was difficult to create a third balancing order with all of the counterbalancing constraints, the third sequence (i.e., "writing") consisted of the same counterbalancing order as "wrapping", but the order of the sequences was scrambled. The counterbalancing preserved the necessary constraints and ensured that individuals did not implicitly learn any preset order to the sequences in the blocks.

The practice session of the SA paradigm was done with pictures of the steps in binders (pictures measured 22.5cm X 16.5cm) to minimize any discomfort participants may feel first learning the task on the computer. The participants were required to turn the pages at his/her own pace and verbalize when their target step is on the present page. If the picture on the page was a distractor, they were expected to simply turn the page. In addition, every testing room was equipped with a memory aid for each task (see Appendix A). This was a sheet of paper with the eight steps of the task written below the pictorial representation that is on the computer screen. This helped ensure that the participants did not feel that this was a memory test but rather a test of sequential action regulation. In addition, it ensured no confusion as to which step a given picture represented.

The test was programmed to present each picture for 1250 ms on the screen. The 1250 ms stimulus presentation is an estimate of the time needed obtained from previous studies (Chow, 2002). After each stimulus, if the participant answered incorrectly, there was a feedback screen. The feedback screens were white, with 40 Arial font alerting the participants to the fact that they had made an error and told them which step in the sequence they were to monitor for next, including a pictorial representation of the step. These screens lasted as long as the participant wished to view them. The screens helped ensure that participants focused on the next step in the sequence thereby yielding meaningful data for each sequence, even if an error is made during one of the steps. The dependent variables included accuracy scores (for the level of performance analyses), and RT scores (on the correctly responded to items for the intraindividual variability analyses).

*Follow-Up Questionnaire*. Participants were given a short questionnaire to fill out (see Appendix E). The questionnaire asked the participants to rate the familiarity of the three tasks used in the study, as well as to rate the frequency that they had performed this task in the past (on a seven point Likert scale). This questionnaire was meant to ensure that age group or task effects associated with familiarity or frequency would not confound either the level of performance or intraindividual variability analyses.

*Neuropsychological measures*. Three neuropsychological measures were chosen to represent clinical tests of executive functioning. These three tests were chosen due to the importance of examining inhibition, random generation of responses, and visuospatial abilities when conceptualizing executive functioning (Lamar, Zonderman, & Resnick, 2002; Miyake et al., 2000; Robbins et al., 1998). More specifically, Miyake et al. (2000) point to the intercorrelation of random number generation and measures of inhibition that could be important to consider in examining age differences in executive functioning. Additionally, Miyake et al. (2001) specifically point to the importance of examining visuospatial abilities when considering executive functioning.

The Stroop test was chosen as the measure of inhibition due to the robust finding of age group differences in performance (Bryan & Luszcz, 2000). Many versions of the Stroop test are used to detect differences between clinical populations (Bohnen, Jolles, & Twijnstra, 1992; Holst & Villki, 1988), as well as to detect age differences in performance (Cohn, Dustman, & Bradford, 1984; Daigneault et al., 1992). The paper and pencil version of the Stroop test by Psychological Assessment Resources Inc. was administered due to its quick administration and previous demonstration of age group differences in performance (MacLeod, 1991). It consisted of 112 trials in both the colour condition in which participants stated the colour of the asterisks, and the colour-word condition in which the participants read the colour of the ink instead of stating the colour in which the word was printed.

In the Random Generation Test (RGT), participants were asked to generate as many letters of the alphabet as possible in random order for 60 seconds. The dependent variables included the frequency of each letter, and the frequency of letter pairs (assessing redundancy), as well as the frequency of letter pairs in alphabetical sequence (assessing stereotyped responses). This test was chosen as a potentially additional indicator of inhibition, as well as a pure test of random generation. It has also been noted as a sensitive test for sub clinical populations (Lezak, 1995).

The Visual Span test subtest of the WMS-III (Psychological Corporation, 1997b) was given as an additional indicator of visuospatial abilities (in addition to the the SA paradigm which has inherent visuospatial demands). Participants were asked to memorize and tap the blocks in the same order in which the examiner tapped the blocks for each trial. The dependent variable was the longest span in which a participant successfully tapped the blocks in the correct sequence for 2 trials in a row. Its norms also facilitate a manipulation check to ensure that there is nothing idiosyncratic in the cognitive functioning of both the younger and older adults. The test permits an analysis of visuospatial working memory.

*Design and Procedure*

The study took place across three testing sessions that were approximately one week apart. On the first occasion, demographic information was collected and then the first session of testing commenced. On the subsequent two occasions, the participants were repeatedly tested on the experimental and neuropsychological executive functioning measures.

During the first testing session, participants were given a demographic questionnaire to fill out asking about their chronological age, self-reported health, years of education, and medical conditions (see Appendix E). Afterward, the Digit Symbol test was administered as an independent measure of speed of processing (Salthouse, 1996). Following the digit symbol test, participants were instructed that they would have to complete a computerized task that requires individuals to monitor the steps required to perform a specified task (Sequential Action [SA] paradigm). Participants were asked to memorize the steps to "writing". Afterwards, they were given practice trials in a binder that replicated the computerized pictures that the individual later saw on the computer screen. Once the participants sufficiently understood the task, they commenced the computerized portion of the SA paradigm. All participants were seated in front of the monitor, approximately 30-60 cm. from the screen. There were ten instruction screens that the participants were encouraged to go over (see Appendix B). After the tenth screen, participants were informed that the testing portion of the paradigm would begin.

After the SA paradigm in the first session, three short neuropsychological measures of executive functioning were administered. These measures included the Visual Span subtest of the Wechsler Memory Scales -III (WMS-III; Psychological Corporation, 1997b), the Stroop test (Stroop, 1935), and the Random Generation Task (Baddeley, 1986; Van der Linden, Beerten & Pesenti, 1998). The Random Generation Task was administered twice allowing individuals two trials, of which the average was taken in order to increase the reliability of the measure.

In sessions two and three, participants first repeated "writing" from the SA paradigm. Afterward, they completed another block from the SA paradigm. In session two, half of the participants completed "wrapping" as their additional block, and the other half of the participants completed "smoking". In Session three, "writing" was first administered to all participants, and the block that they had not yet completed was administered afterward. This ensured that after all three sessions, all participants would have completed the "writing" block three times, the "wrapping" block once, and the "smoking" block once. After the SA paradigm, participants were administered the Visual

Span test, the Stroop test, and two trials of the Random Generation Task in order to assess intraindividual variability across the three sessions. After the final session, participants were given a scale to evaluate how familiar they were with all three tasks, and how frequently they engaged in them (see Appendix E). Lastly, participants were debriefed about the purpose of the experiment and given an honorarium of 30 dollars for their time.

## Results I: Analysis of Sequential Performance

The primary goal of this study was to examine sequential behaviour within the context of executive functioning. Chapter 3 is focused on the SA paradigm in order to examine the hypothesized processes that govern sequential behaviour, namely inhibitory mechanisms. In the subsequent results chapter executive processes are addressed by analyzing age differences in the neuropsychological measures of executive functioning. Additionally, this chapter examines whether performance on the neuropsychological measures could be correlated to the processes revealed in the SA paradigm. Lastly, intraindividual variability in all measures of executive functioning was analyzed addressing the issue of whether there is shared variance within these measures in both level of performance and variability.

In the current chapter, age differences in the underlying mechanisms of sequential behaviour (i.e. inhibitory mechanisms) were examined in a naturalistic action sequence. More specifically, the first analysis addresses the question of whether the pattern of intrusion errors in all three tasks supports the existence of both lateral (as described in Li et al., 2000) and self-inhibition in younger and older adults.

*Data Preparation*

In order to examine both lateral and self-inhibition, the pattern of intrusion errors was analyzed. RT data was not considered for this set of analyses. When a participant responded to a step that was not the step that they were supposed to be monitoring for in the sequence, it was considered an intrusion error. Intrusion errors were classified in terms of their ordinal distance from the current target step (consistent with Li et al., 2000). For example, if a participant were monitoring for Step 3, but in the interim responded to Step 1, that would be considered a Lag -2 error. Similarly, if a participant were monitoring for Step 3, but in the interim responded to Step 5, that would be considered a Lag +2 error. All intrusion errors (distractors) were classified according to the following categories: Lag $\leq$ -5, Lag -4, Lag -3, Lag -2, Lag -1, Lag +1, Lag +2, Lag +3, Lag +4, Lag $\geq$ +5. Lag 0 was considered a 'hit' as it was representative of the target step that a participant was supposed to respond to. Before the rate of intrusion errors was computed, the data were screened for invalid responses to distractors. Any responses that were made within 10 milliseconds, as well as responses that were made with the wrong key (i.e., the "next" key) were eliminated[2]. These responses were not considered bona fide intrusion errors. The rate of intrusion errors was then computed by dividing the number of intrusion errors by the total number of opportunities to produce that type of intrusion error (Lag $\leq$ -5 to Lag $\geq$ +5) within each task and lag bin.

*Screening and Manipulation Checks*

In order to ensure that the memory component of the SA paradigm (i.e. memorizing the steps to complete the tasks) did not differentially impact the older adults, we analyzed the total percentage of omission errors made on each task, within each session. More specifically, we hoped to be examining sequential behaviour independent of any memory demands. A 2 (Age Group) X 3 (Session) ANOVA revealed a significant main effect associated with Session, $\underline{F}$ (2, 39) = 35.67, $\underline{p} < .001$, $\eta^2 = .65$. Consistent with our expectations, participants made more omissions in Session 1 ($\underline{M}$ = 5.89, $\underline{SD}$ = 5.33) than in Session 2 ($\underline{M}$ = 2.90, $\underline{SD}$ = 2.83) and the fewest number of omission errors in Session 3 ($\underline{M}$ = 2.20, $\underline{SD}$ = 2.44). Paired sample t tests on the mean percentage of

[2] The total percentage of responses to intrusions that were eliminated from the analyses was 0.09% for Session 1, and 0.04% for both Session 2 and Session 3.

omission errors across sessions indicate that all participants made significantly fewer omission errors from Session 1 to Session 2, $\underline{t}(41) = 6.63$, $\underline{p} < .001$ but did not make significantly fewer omissions from Session 2 to Session 3, $\underline{t}(41) = 1.72$, $\underline{p} = .09$. [3]

There was also a significant main effect associated with Age Group, $\underline{F}\ (1, 40) = 9.56$, $\underline{p} = .004$, $\eta^2 = .19$, which was qualified by a Session X Age Group interaction, $\underline{F}\ (2, 39) = 7.17$, $\underline{p} = .002$, $\eta^2 = .27$. Older adults made significantly more omissions ($\underline{M} = 5.08$, $\underline{SD} = 3.71$) than younger adults ($\underline{M} = 2.38$, $\underline{SD} = 1.65$). Independent sample t tests comparing age group differences in omissions within each session indicate that there were significant age group differences in omission errors in Session 1, $\underline{t}(40) = -3.26$, $\underline{p} < .001$; Session 2, $\underline{t}(40) = -2.45$, $\underline{p} = .02$[4], and no significant age group differences in Session 3, $p = .17$. Table 2 summarizes the percentage of omission errors made as a function of Age Group and Session.

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Insert Table 2 about here

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A subsequent 2 (Age Group) X 2 (Order[5]) X 2 (Session) ANOVA was carried out to analyze the percentage of omission errors on the other two tasks, and to examine if there was any main effect associated with Order. This ANOVA revealed a significant main effect associated with Age Group, $\underline{F}\ (1, 38) = 7.27$, $\underline{p} = .01$, $\eta^2 = .16$. Older adults

[3] All the significant results of post hoc tests remained significant using Bonferroni correcctions unless otherwise indicated.
[4] Equality of variances was not assumed for Session 1 and 2, therefore the corrected t statistic is reported.
[5] Order indicates the order in which participants performed the blocks. In Session 2, half of the participants were tested on "wrapping", and the other half were tested on "smoking". In Session 3, the participants completed the block which they had not yet done in Session 2.

made significantly more omissions ($\underline{M}$ = 4.01, $\underline{SD}$ = 3.14) than younger adults ($\underline{M}$ = 1.94, $\underline{SD}$ = 1.40). There were no other significant effects or interactions.

Taken together, these analyses on the accuracy/error data indicate that this newly developed variant of the SA task did not overtax participants' memory resources. Omission error rates made were low enough so as to assume that all participants were able to memorize the steps required to perform each task. Of particular concern was whether this task would inadvertently penalize older adults due to short stimulus durations and a demand on their memory load. Results reveal that while there were significant age differences in the number of omission errors made, older adults performed similarly to the younger adults by Session 3 indicating that the differential impact of the memory demand on older adults was minimized although not entirely eliminated. Therefore, in subsequent analyses it is assumed that the results reflect the processes that govern sequential behaviour with minimal interference from the memory demands of the task.

To ensure that task familiarity and frequency of engagement did not differentially impact performance for one age group over the other, participants were given the follow up questionnaire asking them to rate on a scale of 1 to 5 how familiar and how frequently they engaged in the 3 given tasks. As we expected given the advent of electronic mail, older adults did report that they engaged in letter writing more frequently than younger adults, $\underline{F}$ (1, 39) = 12.99, $\underline{p}$ = .001, $\eta^2$ = .25. This finding suggests that older adults were not penalized or overly taxed due to unfamiliar tasks and if anything, the contrary was possible. There were no other significant age group differences for "smoking a cigarette" or "wrapping a gift" ensuring that task familiarity and frequency of engagement did not serve as a confounding variable in our analyses.

*Level of Performance*

We examined level of performance on the SA paradigm to try and understand the underlying mechanisms that govern sequential behaviour. More specifically, we were interested in whether the accuracy/error data showed evidence of both lateral and self-inhibition being utilized (similar to Li et al., 2000), or whether there was only evidence for self-inhibition because of our more naturalistic sequences, similar to Chow (2002). In order to examine inhibitory processes in the SA paradigm, we examined the pattern of intrusion errors across the different lag bins. Lateral inhibition was examined by comparing the percentage of intrusion errors made across all lag bins. Because self inhibition is likely time limited, we analyzed the percentage of intrusion errors made in only the Lag +1 and Lag -1 conditions.

*Lateral inhibition in "writing".* We computed a 2 (Age Group) X 10 (Lag) X 3 (Session) repeated measures analysis of variance (ANOVA) on the rate of intrusion errors for "writing" in order to examine lateral inhibition. The analysis on the intrusion errors in "writing" indicated that there was a significant main effect associated with Session, $\underline{F}$ (2, 39) = 15.46, $\underline{p} < .001$, $\eta^2 = .44$. Participants made more intrusion errors in the first session and improved significantly across sessions with the least number of intrusion errors in the last session. Tests of within-subjects contrasts indicated significant linear, $\underline{F}$ (2, 39) = 30.81, $\underline{p} < .001$, $\eta^2 = .44$ and quadratic, $\underline{F}$ (2, 39) = 6.38, $\underline{p} = .016$, $\eta^2 = .14$ trends associated with session. Paired sample t tests on the mean number of intrusion errors for each session indicated that there was a significant difference in mean number of intrusion levels from Session 1 to Session 2, $t(41) = 4.67$, $p < .001$, Session 2 to Session 3, $t(41) = 2.23$, $p = .03$, and Session 1 to Session 3, $t(41) = 4.77$, $p < .001$. These analyses indicate that there was a larger gain in performance (fewer intrusion errors) from Session 1 to Session 2 than there was from Session 2 to Session 3.

There was also a significant main effect associated with Lag, $F(9, 32) = 18.70$, $p < .001$, $\eta^2 = .84$. Tests of within-subjects contrasts were examined in order to investigate whether there was any evidence for lateral inhibition. There was a significant quadratic trend associated with Lag, $F(9, 32) = 124.85$, $p < .001$, $\eta^2 = .76$. This quadratic trend is not illustrative of lateral inhibition (as in Li et al., 2000) because it is in the shape of an inverse U (as opposed to a U shape), which is likely due to the visual similarity between steps in a naturalistic sequence. Figure 1 illustrates the percentage of intrusion errors by lag and age group.

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Insert Figure 1 about here

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There was also a significant Session X Age Group interaction, $F(2, 39) = 6.36$, $p < .01$, $\eta^2 = .25$. Independent sample t tests on the mean number of intrusion errors across lag bins indicate that there were significant age group differences in Session 1, $t(40) = -2.30$, $p = .03$, and none in Sessions 2 or 3, $ps = 0.34$ and $0.52$ respectively. This is likely a result of older adults improving across sessions at a faster rate than younger adults.

Lastly, there was an additional significant Session X Lag interaction, $F(18, 23) = 3.10$, $p < .01$, $\eta^2 = .71$. Repeated Measures ANOVAs were carried out in order to investigate the polynomial contrasts within each session. In Session 1, there were significant linear, $\underline{F}$ (1,40) = 9.85, $\underline{p}$ < .001, $\eta^2$ = .20 and quadratic $\underline{F}$ (1, 40) = 104.94, $\underline{p}$ < .001, $\eta^2$ = .72 trends associated with lag. In Session 2, there were also significant linear, $\underline{F}$ (1,40) = 7.58, $\underline{p}$ = .01, $\eta^2$ = .20 and quadratic $\underline{F}$ (1, 40) = 85.47, $\underline{p}$ < .001, $\eta^2$ = .68 trends associated with lag. By Session 3, the linear trend disappeared, $\underline{p}$ = .18, and a significant quadratic trend remained, $\underline{F}$ (1, 40) = 51.18, $\underline{p}$ < .001, $\eta^2$ = .56. The disappearance of the linear trend is partially due to the decrease of self-inhibition (i.e. the slope from Lag -1 to Lag +1) across sessions. A more detailed analysis of self-inhibition within "writing" examines this further.

*Lateral inhibition in "wrapping" and "smoking".* We computed a 2 (Age Group) X 2 (Order) X 10 (Lag) X 2 (Session) repeated measures ANOVA on the rate of intrusion errors for "wrapping" and "smoking" in order to examine lateral inhibition (as was defined in Li et al., 2000). The analysis on the intrusion errors indicated that there was a significant main effect associated with Lag, $\underline{F}$ (9, 30) = 15.33, $\underline{p}$ < .001, $\eta^2$ = .82 indicating that participants performed differently in the lag conditions (see Table 4 for the percentage of errors in each lag for "wrapping" and "smoking"). Post hoc polynomial contrasts indicated a significant quadratic trend associated with Lag, $\underline{F}$ (1, 38) = 90.18, $\underline{p}$ < .001, $\eta^2$ = .70. This quadratic trend is also not illustrative of lateral inhibition (as in Li et al., 2000) because it is also in the shape of an inverse U. There was also a significant Lag X Age Group interaction, $\underline{F}$ (9, 30) = 2.84, $\underline{p}$ = .02, $\eta^2$ = .46. Post hoc polynomial contrasts indicated that there was no significant quadratic trend associated with Lag X Age Group, $\underline{p}$ = .25. Figures 2 and 3 illustrate the percentage of intrusion errors by lag and age group for "wrapping" and "smoking".

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Insert Figures 2 and 3 about here

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*Self-inhibition in "writing".* We investigated self-inhibition by computing a 2 (Age Group) X 2 (Lag) X 3 (Session) repeated measures ANOVA on the rate of intrusion errors in Lags +1 and -1 in the "writing" block. If participants made more anticipatory errors than perseveratory errors, this was seen as evidence for self- inhibition. We predicted that there would be a greater percentage of errors made in the Lag +1 condition versus the Lag -1 condition. Furthermore, in line with other research, the magnitude of asymmetry would be smaller for older adults because their self inhibitory capabilities are reduced. Tables 3 and 4 summarize the mean percentage of intrusion errors in each lag across age group, block, and session.

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Insert Tables 3 and 4 about here

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The analysis on the intrusion errors in Lags +1 and -1 indicated that there was a significant main effect associated with Lag, $\underline{F}$ (1, 40) = 136.33, $\underline{p}$ <.001, $\eta^2 = .77$. As expected, participants had a higher percentage of intrusions errors in the Lag +1 bin ($\underline{M}$ = 14.25, $\underline{SD}$ = 8.22) than in the Lag -1 bin ($\underline{M}$ = 2.29, $\underline{SD}$ = 2.62). Additionally, there was a significant main effect associated with Session, $\underline{F}$ (2, 39) = 17.23, $\underline{p}$ <.001, $\eta^2 = .47$. All participants had the greatest number of errors in Session 1 ($\underline{M}$ = 12.41, $\underline{SD}$ = 8.09), and progressively made fewer errors in Session 2 ($\underline{M}$ = 7.63 $\underline{SD}$ = 5.44), and finally in Session 3 ($\underline{M}$ = 5.74, $\underline{SD}$ = 4.85).

There were also significant interactions associated with Session X Age Group, $F$ (2, 39) = 5.51, $p = .01$, $\eta^2 = .22$, Lag X Age Group, $F$ (1, 40) = 7.02, $p = .01$, $\eta^2 = .15$, Session X Lag, $F$ (2, 39) = 9.28, $p = .001$, $\eta^2 = .32$, and Session X Lag X Age Group, $F$ (2, 39) = 4.14, $p = .02$, $\eta^2 = .18$. Paired sample t tests on the percentage of intrusion errors in Lag +1 compared to Lag -1 indicated that there was a significant effect of Lag in Session 1, $t(41) = 9.54$, $p < .001$, Session 2, $t(41) = 8.38$, $p < .001$, and in Session 3, $t(41) = 6.91$, $p < .001$ illustrating that lag remains significant despite the interaction that indicates that the discrepancy between Lag +1 and Lag -1 declines across occasions. Similarly, paired sample t tests on the percentage of intrusion errors in Lag +1 compared to Lag -1 within each age group and within each occasion indicated that lag remains significant despite the interaction that indicates that the discrepancy between Lag +1 and Lag -1 declines faster in the older adults than in the younger adults across the 3 sessions, $ps < .001$. By Session 3, the lack of age differences for the discrepancy between Lag +1 and Lag -1 could be a result of decreased inhibitory activation due to less rehearsal. Figures 4a and 4b illustrate the main effect of Lag within both Age Group and Session. These figures illustrate self-inhibition in both older and younger adults in all three sessions. Notably, older adults show greater practice effects than the younger adults suggesting the possibility of training to increase self-inhibition for older adults. Alternatively, it is possible that younger adults reached ceiling performance leaving no room for continuous improvement in performance after Session 2. Similarly, because the participants were already nearing zero in error rates at Lag -1, it is conceivable the reduced slope as a function of session is as a result of reduced errors in the Lag +1 condition only.

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Insert Figures 4a and 4b about here

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*Self-inhibition in "wrapping" and "smoking".* A 2 (Age Group) X 2 (Order) X 2 (Lag) X 2 (Session) repeated measures ANOVA on the rate of intrusion errors in Lags +1 and -1 was computed for the "wrapping" and "smoking" blocks. The analysis on the intrusion errors in Lags +1 and -1 indicated that there were significant main effects associated with Lag, $\underline{F}$ (1, 38) = 70.77, $\underline{p}$ <.001, $\eta^2 = .65$. As previously illustrated in "writing", participants had a higher percentage of intrusions errors in the Lag +1 bin ($\underline{M}$ = 12.13, $\underline{SD}$ = 8.34) than in the Lag -1 bin ($\underline{M}$ = 3.87, $\underline{SD}$ = 4.84).

There is also a significant Session X Order interaction, $\underline{F}$ (1, 38) = 6.01, $\underline{p}$ = .02, $\eta^2 = .14$. Paired Samples t tests on the percentage of intrusion errors in Sessions 2 and 3 for those who received "smoking" first (Order 1) indicated that they did not perform significantly differently from Session 2 ($\underline{M}$ = 7.71) to Session 3 ($\underline{M}$ = 8.00). Conversely, those who received "wrapping" first (Order 2) performed significantly better in Session 3 (M = 5.91) than in Session 2 (M = 9.52), $\underline{t}$(21) = 2.74, $\underline{p}$ = .01.

Additionally, due to our a priori hypothesis that participants would perform similarly on each task, we conducted post hoc analyses examining whether there was a significant lag effect within each task. Despite the Session X Order effect reported previously, we confirmed that there were significant lag effects within each task (i.e. a null Session X Lag interaction) when contrasting Lag -1 and Lag +1. Paired samples t tests illustrated that there was a significant effect of lag for "smoking", $\underline{t}$(41) = 4.07, $\underline{p}$ < .001, and for "wrapping", $\underline{t}$(41) = 9.11, $\underline{p}$ < .001. This illustrates that the construct of self-inhibition held for each task independent of the ordering effect mentioned above. Figures 5a and 5b illustrate the main effect of Lag by Age Group within each task.

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Insert Figures 5a and 5b about here

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*Summary*

Taken together, these findings indicate that the same processes govern sequential behaviour for both younger and older adults. The results from the analyses on the accuracy/error data revealed evidence for self-inhibition (as defined in Li et al., 2000) across all three tasks, and sessions despite the age group differences in magnitude of intrusion errors. Younger adults did initially demonstrate greater self inhibitory skills compared to older adults. Older adults showed substantially greater improvement across the session suggesting the possibility of training to increase their self inhibitory skills in sequential performance. Further evidence of similar processes governing both age groups was the lack of evidence for lateral inhibition in any of the tasks, across the three sessions. This was likely due to the effects of visual similarity in naturalistic sequences which will be further explored in Chapter 5.

## Results II: Executive Functioning in Performance Levels and Intraindividual Variability

The next set of analyses were carried out to examine whether there are age group differences in the neuropsychological measures of executive functioning, and whether these measures correlate with one another, and with sequential action measures. More specifically, we utilized the Stroop task as a measure of inhibition, the Random Generation task as an additional indicator of inhibition in a different context, and the Visual Span test as a measure of visuo-spatial working memory. While these three tasks do not represent executive functioning exhaustively, they are all known measures of executive processes, and they are also diverse enough to warrant theoretical interest in the investigation of their intercorrelations.

The second portion of this chapter addresses the question of whether there are significant age differences in intraindividual variability on both the neuropsychological measures and the SA paradigm measures. Intraindividual variability estimates were derived from the RT data from the SA paradigm and the Stroop Task, and from the accuracy scores from the Random Generation Task and Visual Span Test. These analyses were carried out to investigate whether variability on these executive measures could aid in explaining age group differences associated with executive functioning. That is, given theoretical claims that it is difficult to determine level of executive functioning in older adults (e.g., Bryan & Luszcz, 2000), we were interested in examining whether intraindividual variability on executive tasks yielded clearer age group differences. We are also interested in examining whether variability correlates with level of performance on executive functioning tests. This would provide further evidence for the frontal involvement in both intraindividual variability and executive functioning, and facilitate a better understanding of all of the phenomena that may be accounted for by executive functioning.

*Level of Performance in Neuropsychological Measures*

For each of the neuropsychological measures, we computed separate 2 (Age Group) X 3 (Session) repeated measures ANOVAS on the scores generated by the Stroop and Visual Span tasks. For the Stroop task, we analyzed RT proportional difference scores[6]. For the Visual Span task, we analyzed the reliable visual span for both backward and forward conditions[7].

Similarly, a separate 2 (Age Group) X 3 (Session) X 2 (Time[8]) was performed on the Random Generation Task. A composite score was calculated on this task by adding the number of random letters generated and subtracting any errors made from this score.

*Level of performance on Stroop proportional difference latency scores.* The analysis of the proportional difference scores indicated that there was a significant effect of Age Group, $\underline{F}$ (1, 40) = 8.18, $\underline{p}$ = .01, $\eta^2 = .17$. Older adults were proportionately more slowed ($\underline{M}$ = 0.92, $\underline{SD}$ = 0.50) than younger adults ($\underline{M}$ = 0.59, $\underline{SD}$ = 0.22) by the interference condition. There were no other significant main effects or interactions associated with the Stroop task.

*Level of performance on Visual Span scores.* The analysis of the forward reliable visual span indicated that there was a significant effect of Age Group, $\underline{F}$ (1, 40) = 11.23, $\underline{p}$ = .002, $\eta^2 = .22$. Older participants produced a smaller forward reliable visual span ($\underline{M}$ = 3.28, $\underline{SD}$ = 0.91) than did younger participants ($\underline{M}$ = 4.24, $\underline{SD}$ = 0.93).

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[6] Proportional difference scores were derived by calculating CW-C/C for total reaction time and dividing the result by the total number of items completed (as in Levinoff, Li, Murtha, & Chertkow, 2004).
[7] The reliable spans are those in which the participant has successfully 2 trials at the given span length (Psychological Corporation, 1997b).
[8] Time is the 1st or 2nd performance of the task in each session

The analysis of the backward reliable visual span indicated that there were significant effects associated with Session, $\underline{F}$ (2, 39) = 10.87, $\underline{p} < .001$, $\eta^2 = .36$ and Age Group, $\underline{F}$ (1, 40) = 5.24, $\underline{p} = .03$, $\eta^2 = .12$. Paired sample t tests on backward reliable visual span across sessions indicated that participants improved significantly from Session 1 to Session 2 $\underline{t}(41) = 3.21$, $\underline{p} = .003$, but did not attain a significantly higher visual span from Session 2 to Session 3, $\underline{p} = 0.47$. Older adults had a significantly smaller backward visual span ($\underline{M}$ = 3.28, $\underline{SD}$ = 0.84) than did younger participants ($\underline{M}$ = 3.94, $\underline{SD}$ = 1.00). There were no other significant main effects or interactions associated with the Visual Span measures.

*Level of performance on Random Generation task.* The analysis on the Random Generation measures indicated that there were significant main effects associated with Session, $\underline{F}$ (2, 39) = 10.06, $\underline{p} < .001$, $\eta^2 = .34$. Paired sample t tests on Random Generation measures across sessions indicated that participants improved significantly from Session 1 to Session 2 $\underline{t}(41) = 2.58$, $\underline{p} = .01$ and similarly from Session 2 to Session 3, $\underline{t}(41) = 2.7$, $\underline{p} = .01$. Contrary to the previous neuropsychological measures, there were no other significant main effects or interactions associated with the random generation measures.

*Summary.* The results of the analyses of neuropsychological measures of executive functioning support theoretical claims (Miyake et al., 2000; Salthouse et al., 2003) that executive functioning may be a multifaceted construct in that all three measures did not yield uniform age main effects or interactions. Notably, RGT did not yield significant age group differences illustrating the veracity of Bryan and Luszcz's (2000) claim that standardized neuropsychological measures of executive functioning may not be sufficiently sensitive to illustrate age differences therein (or there are no bona fide age group differences in the task). Additionally, practice effects were observed with the Visual Span task and the Random Generation task but these practice effects do not hold with the Stroop Task.

*Correlations Between Level of Performance in the Neuropsychological Measures and the SA Paradigm*

The relationships between the Stroop task, Visual Span, Random Generation task and the SA paradigm were examined in order to identify any shared variance among the tasks. More specifically, we were interested in examining whether the SA paradigm shared any variance with the standardized tests of executive functioning. Given that previous literature suggests that executive functioning is largely a multifaceted construct (Miyake et al., 2000; Salthouse et al., 2003), we expected minimal correlations between these measures. However, given that these tasks have previously been utilized to demonstrate age differences in performance (Bryan & Luszcz, 2000; MacLeod, 1991; Miyake et al., 2000, Psychological Corporation, 1997b), some modest correlations between measures would also be expected. For a summary of these intercorrelations, see Tables 5a and 5b.

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Insert Tables 5a and 5b about here

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*Relationships in level of performance across neuropsychological measures.* Because these neuropsychological measures are usually most taxing during the first administration, and there are practice effects thereafter, we examined the correlations between neuropsychological measures within Session 1, and measures that were averaged across all 3 sessions. The derived variable served to take into consideration any improvement in performance subsequent to Session 1.

Among the older adults, there were no significant correlations between measures both in Session 1, and across all sessions (except for a significant relationship between reliable forward visual span in Session 1, and reliable backward visual span across sessions, $\underline{r} = .48$, $\underline{p} = .05$). Among the younger adults there was a significant relationship between reliable forward visual span and reliable backward visual span in Session 1, $\underline{r} = .70$, $\underline{p} < .001$, and across all sessions, $\underline{r} = .75$, $\underline{p} < .001$. This suggests that young adults who had a high forward visual span had a similarly high backward visual span. Interestingly, there is only one correlation that shows the same pattern for the older adults. As we hypothesized, there was only one significant correlation in level of performance across the different neuropsychological measures for older adults and slightly more correlations for younger adults.

*Correlations across the neuropsychological measures, intrusion errors and omission errors on the SA paradigm.* To examine the correlations between the SA errors and the neuropsychological measures, we used the first occasion measures from the SA paradigm as well as an average across the three sessions for "writing".[9]

Among the older adults, there were no significant correlations across the different measures of executive functioning both in Session 1, and across all sessions. Within the SA paradigm, the percentage of omissions errors made was significantly correlated to the percentage of intrusion errors both within Session 1 and across the three sessions,

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[9] Block 2 was used (writing and posting a letter) in this analysis because the blocks did not differ significantly in our results and this block was given across all 3 sessions.

correlations ranged from .50 to .58. This indicates that for older adults, if an individual made many omission errors, they likely made a number of intrusion errors as well.

Conversely, there were significant correlations between Visual Span measures and SA measures both within Session 1 and across sessions for younger adults. Within Session 1, there were significant correlations between reliable backward span and omission errors, $r = -.47$, $p = .03$, reliable forward span and omission errors, $r = -.43$, $p = .04$, reliable backward span and intrusion errors, $r = -.49$, $p = .02$, and reliable forward span and intrusion errors, $r = -.43$, $p = .04$. These correlations suggest that when younger adults had higher visual spans (either forward or backward span), they made fewer omission and intrusion errors. Notably, the backward visual span was more strongly correlated with performance on the SA paradigm than was forward visual span. Both for Session 1, and for average performance across all three sessions, the results were similar illustrating significant correlations between reliable backward visual span and percentage of omission errors, $r = -.61$, $p < .001$, reliable forward visual span and percentage of omission errors, $r = -.53$, $p = .01$, and reliable backward visual span and percentage of intrusion errors, $r = -.60$, $p < .001$.

*Summary.* The correlational data illustrate that for the older adults, there are no significant correlations across the measures of executive functioning. Within the SA paradigm, intrusion errors were correlated with omission errors in that the more intrusions an individual made, the more omission errors they made as well. Interestingly, the two measures of the Visual Span test were not correlated with one another. These results suggest a differentiation of cognitive abilities (on these measures of executive functioning) among the older adults. The notion that older adults' performance varies on different measures of executive functioning could be indicative of one of the problems assessing age differences in these cognitive functions (as mentioned in Chapter 1).

For the younger adults, the backward and forward measures of the Visual Span test were correlated. In addition, the younger adults' data were such that the higher their visual span was (either backward or forward), the fewer omissions and intrusion errors they made on the SA paradigm. This could be reflective of the efficiency of younger adults' inhibitory skills. More specifically, younger adults successfully inhibit distractors in both the Visual Span Test (other numbers on the board) and the SA paradigm (other steps in the sequence) resulting in fewer errors and higher visual spans.

This examination of intercorrelations among measures of executive functioning was more informative about the younger adults than it was about the older adults. However, examining intraindividual variability in performance adds another dimension that could be informative for both age groups because there may be correlations across these measures using both level of performance and variability as dependent variables.

*Intraindividual Variability in Neuropsychological Measures of Executive Functioning and the Latency Scores on the SA Paradigm*

In order to examine intraindividual variability, the first concern was to purify the RT data for any systematic effects associated with occasion (e.g., practice effects), mean differences across age groups, or across targets in the tasks from the SA paradigm. After purifying for systematic effects, the inconsistency in performance, independent of any durable change that is related to development or learning was analyzed. The purification procedure (consisting of regressing occasion, group, and target number on the trial RT scores) helped dissociate state from trait variability allowing a statistical examination of the state variability in this data set. The residual scores (which are typically considered error) were considered as an estimate of intraindividual variability uncontaminated by systematic variation due to materials or practice effects. The residuals were then standardized by creating T scores in order to allow for comparison across the SA paradigm and the neuropsychological measures. Next, intraindividual standard deviations (ISD) were computed from the residual scores for each individual across the three occasions. The Coefficient of Variation (CV) was also computed from the residual scores in which an individual's ISD is divided by their own mean score. This provides a measure of intraindividual variability relative to the individual's own level of performance (e.g, Hultsch et al., 2000; Segalowitz, Poulsen & Segalowitz, 1998).

For these analyses, we computed separate ANOVAS to examine the effect of Age Group on the intraindividual variability measures from the scores generated by the Stroop, Random Generation and Visual Span tasks. For the SA paradigm, we calculated separate ANOVAs to examine the effect of Age Group on the within session latency ISDs and CVs, as well as across occasion latency ISDs and CVs.

*Intraindividual variability in Stroop, Random Generation, and Visual Span across sessions.* The analysis of ISDs and CVs for these tasks revealed no significant main effects of Age Group.

*Intraindividual variability in SA paradigm latency scores to sequential targets within session one.* The reaction time scores to target steps on the SA paradigm were used to derive ISDs and CVs. For a summary of the reaction time scores that were used to derive the variability measures, see Table 6. The analysis of the ISDs revealed a significant main effect associated with Age Group, $\underline{F}$ (1, 41) = 10.66, $\underline{p} < .001$, $\eta^2 = .21$

indicating that older adults were more variable in their reaction times (M = 9.91, SD = 2.14) than younger adults (M = 8.10, SD = 1.48). The analysis using the CVs revealed the same main effect associated with Age Group, $F\ (1, 41) = 16.19$, $p < .001$, $\eta^2 = .28$ indicating that older adults were more variable in their reaction times (M = 0.20, SD = 0.03) than younger adults (M = 0.16, SD = 0.02).

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Insert Table 6 about here

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*Intraindividual variability in SA paradigm latency scores to sequential targets across sessions.* This analysis is similar to that examining intraindividual variability in Session 1 in that after purification, ISD and CV scores were computed for each individual. In order to make use of the data from all sessions, this analysis also purified for session effects, and then derived ISD and CV scores for participants.

The analysis of ISDs showed a significant main effect associated with Age Group, $F\ (1, 40) = 4.26$, $p = .05$, $\eta^2 = .10$, indicating that older adults were more variable in their reaction times (M = 9.66, SD = 2.01) than younger adults (M = 8.52, SD = 1.55). The analysis using the CVs revealed the same main effect associated with Age Group, $F\ (1, 40) = 5.87$, $p = .02$, $\eta^2 = .13$, indicating that older adults were more variable in their reaction times (M = 0.19, SD = 0.03) than younger adults (M = 0.17, SD = 0.03).

In sum, these analyses revealed that the older adults were more variable than younger adults both within Session 1, and across the three sessions in reaction times on the SA paradigm. That is, independent of any age group differences in reaction times, the older adults were systematically more variable from trial to trial and across all three occasions than the younger adults were. This increased intraindividual variability in older adults is consistent with previous findings (eg., Hultsch et al., 2000) and could in and of itself be an indicator of compromised frontal functioning which is considered to be the seat of executive functioning. Contrary to this finding, there were no significant age group differences in IV across the neuropsychological measures. This is addressed further in the discussion.

*Relationship of the ISDs and CVs of the neuropsychological measures, and the SA paradigm.* There were a number of significant correlations indicating that variability in performance was correlated across the measures of executive functioning (see Tables 7a and 7b)[10]. Among the younger adults, there were no significant correlations.

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Insert Tables 7a and 7b about here

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Among the older adults, there were a number of significant correlations indicating that intraindividual variability in the SA paradigm is correlated with some neuropsychological measures. The SA paradigm's ISD within session one was significantly correlated with the Stroop ISD, $r = .48$, $p = .01$; the Stroop CV, $r = .54$, $p = .01$; The Random Generation Task ISD, $r = -.47$, $p = .04$; and The Random Generation Task CV, $r = -.45$, $p = .05$. These correlations indicate that the more variable a person is on the first occasion of the SA paradigm, the *more variable* they will be on the Stroop task and the *less variable* they will be on the Random Generation task across sessions. The first correlation is in line with previous literature indicating that increased variability

[10] Because ISDs yielded the same age group effects (and similar correlational patterns) as CVs, only ISDs are tabled.

in one task is predictive of increased variability in another task (e.g., Hultsch et al., 2000). The correlation indicating that the more variable individuals were on the SA paradigm, the less variable they were on the Random Generation Task was contrary to our hypotheses. The reason for this finding could be related to the strategy used to successfully complete the Random Generation Task. This is explored further in the Discussion.

*Relationship between level of performance on executive functioning tests and intraindividual variability on these tests.* Both the younger and older adults demonstrated significant correlations between level of performance and intraindividual variability on the various tests (see Tables 5a and 5b).

Within the SA paradigm, the correlations among both older and younger adults indicate that the greater number of intrusion and omission errors individuals made, the greater the intraindividual variability in RT both within sessions and across sessions. Among the older adults, significant correlations between level of performance and intraindividual variability on the SA paradigm ranged from .52 to .77. For example, the percentage of omission errors made within Session 1 was correlated with the ISD on the SA paradigm, $\underline{r} = .77$, $\underline{p} < .001$. Similarly, among the younger adults, significant correlations between level of performance and variability on the SA paradigm ranged from .45 to .76. For example, the percentage of omission errors made was correlated with the ISD on the SA paradigm within Session 1, $\underline{r} = .76$, $\underline{p} < .001$.

Across all measures of executive functioning, there are modest correlations indicating that the worse an individual performs on a given task, the more variable they are in their responses across sessions (with the noted exception of the Random

Generation Task in which the better an individual performed on the task, the more variable they were on other measures of executive functioning). For example, among older adults, the greater the percentage of omission errors made across sessions, the more variable older adults were in their RTs on the SA paradigm across the three sessions, $r = .73$, $p < .001$. Similarly, among younger adults, the greater the percentage of omission errors made across sessions, the more variable the individuals were in their RTs on the SA paradigm across sessions, $r = .67$, $p < .001$.

*Summary*

The analyses from the first portion of this chapter revealed that there were significant age group differences in level of performance in both the Stroop Task and the Visual Span Task. In contrast to our hypothesis, the Random Generation task did not yield any significant age group differences of level of performance. While this is contrary to our hypothesis, it does illustrate the difficulty replicating age group differences in executive functioning tasks that involve strategy and less working memory or processing speed which are more typically identified as declining in older adults.

An analysis of the correlations between these measures indicated some significant correlations for younger adults across the tests, but none for older adults. Among the younger adults, there was also evidence that level of performance on the SA paradigm correlated to both components of the Visual Span Test. This is illustrative of a more diffuse set of executive processes for older adults given the lack of intercorrelations across the tasks, than for younger adults.

The second set of analyses revealed that there were no significant age group differences in intraindividual variability on the neuropsychological measures. However, upon examination of the intercorrlations between level of performance and variability on the SA paradigm and the neuropsychological measures, there is evidence suggesting that intraindividual variability on the neuropsychological measures is predictive of intraindividual variability on the SA paradigm. For example, for the older adults, level of performance on the SA paradigm was correlated with intraindividual variability on the forward component of the Visual Span task, $r = .46$, $p = .05$. There is additional evidence suggesting that for younger adults, the worse they do on the Stroop Task, the higher their intraindividual variability is on the backward component of the Visual Span test. For older adults, we see similar correlation with the backward component of the Visual Span test indicating that the higher span an individual produces, the more likely they are to be variable on the Random Generation Test. This correlation illustrates that intraindividual variability on the Random Generation Test may be indicative of an adaptive variability as opposed to a maladaptive one (see Allaire & Marsiske, 2005). These findings point to the utility in examining intraindividual variability on all measures to better understand executive functioning in older adults.

In sum, the results reveal that performance on these measures vary from task to task but taken together with intraindividual variability (a frontal/executive construct; Bellgrove et al., 2004) one can better ascertain level of functioning in older adults. The data also reveal that among the younger adults, performance on executive functioning measures is more strongly correlated (albeit with the outcome measures of only two executive functioning tests) as compared to intercorrelations on performance of executive measures with older adults. This is suggestive of executive functioning being a valid (albeit multifaceted) construct that may become more diffuse with age.

Experiment 1b: Visual Similarity Study

The examination of sequential behaviour using the SA paradigm (derived from Li et al., 2000) has yielded evidence suggesting that lateral inhibition governs sequential behaviour (e.g., Li et al., 2000) and evidence suggesting that lateral inhibition does not exist (e.g., Chow, 2002). In Chapter 3, a significant quadratic function was observed while examining for lateral inhibition that is in line with Chow (2002). Given that both Chow (2002) and the present study observed inverse U functions while examining the pattern of intrusion errors for the presence of lateral inhibition, it is important to further investigate the quadratic function for other variables that may be of influence.

More specifically, Rünger (2002) performed a re-analysis of the data from Li et al. (2000) in order to provide a more fine grained assessment of the SA paradigm. Rünger (2002) identified the visual similarity between both targets and distractors as a limitation to the findings of Li et al. (2000). There were particular combinations of stimuli (i.e. letters and numbers) that were more confusable than other pairs of stimuli. Rünger (2002) claimed that this compromised the finding that there were greater intrusion errors made the further the distractor was from the target (i.e. lateral inhibition). More specifically, he claimed that the errors made were an artifact of visual similarity and not a result of the sequential distance from the target. Conversely, visual similarity did not compromise the results that illustrated self-inhibition. For example, when participants were searching for step two, they were most likely to respond to step three as an anticipatory intrusion error. One could not attribute this pattern to visual similarity due to the fact that participants did not err in the opposite direction (when searching for step three, participants did not perseverate and respond to step two) which would be expected if visual similarity was the only process underlying an individual's performance. Rünger's study (2002) clearly illustrates the importance of examining visual similarity between targets and distractors when using the SA paradigm.

Because the current study is investigating age group differences in sequential performance (in contrast to Li et al., 2000; Rünger, 2002), it is also important to examine visual similarity and how it may effect age group differences in performance on the SA paradigm. More specifically, examining age group differences in perceived visual similarity between the stimuli will help address whether confusability between the stimuli accounted for older adults making greater errors than younger adults or whether bona fide age group differences in inhibitory performance accounted for older adults making greater intrusion errors. That being said, it is important to note that the current study allowed participants a greater amount of time to compare the visual similarity of the stimuli in comparison to the previous study. This means that visual similarity could still impact the results in the first experiment despite even if pictures are rated the same for both age groups in the current study.

The issue of visual similarity in the SA paradigm becomes even more paramount when investigating age group differences in sequential behaviour. When monitoring for different steps in a naturalistic sequence, it stands to reason that adjacent steps may appear similar to one another. For example, putting toothpaste on a toothbrush may appear visually similar to putting that toothbrush in one's mouth, which in turn may appear visually similar to brushing one's teeth. Naturalistic sequences require one action to flow from the other which can cause adjacent steps in a sequence to be visually similar in terms of physical proximity of limbs, object placement and/or environmental setting.

Due to the fact that visual discrimination could be more difficult for older adults, it is important to understand visual similarity when investigating age differences in sequential behaviour.

Findings from the visual search and aging literature may be applicable to this issue with one caveat. The paradigms using visual search present targets and distractors simultaneously whereas in the SA paradigm, the targets and distractors are presented one after another. Nevertheless, it is still useful to review the literature on visual search across the lifespan in order to understand the manner in which the issue of visual similarity has been addressed thus far in order to apply it appropriately to the SA paradigm. Early studies found significant age-related impairments in visual search when the target and distractors were similar compared to situations when the targets and distractors were distinctively different (e.g., Rabbitt, 1965). Subsequent studies have revealed that this finding is not as straightforward as it may seem (e.g., Kramer, Martin-Emerson, Larish & Anderson, 1996; Scialfa & Joffe, 1997). For example, Scialfa and Joffe (1997) demonstrated that age deficits increased in the visual search task as a function of difficulty level (e.g., contrast, target orientation). The specific features of target-distractor similarity (e.g., movement, colours, and lines) are important to consider when evaluating age differences in identifying the target amongst an array of distractors.

The present study was undertaken to address the issue of visual similarity between targets and distractors within the SA paradigm. The aim of the study was to help explain the quadratic function (inverse U), and the age differences in the magnitude of error that were observed in the previous study. This was achieved by having an independent sample of younger and older participants rate the similarity between the various combinations of targets and distractors within the SA paradigm. We expected individuals to rate immediately adjacent steps as more similar than steps that are more ordinally distant from one another. If observed, this would be in line with Rünger's (2000) claim that the U function could be a result of visual similarity between targets. We did not hypothesize age group differences in the similarity ratings. This null age effect would confirm that both age groups perceive the stimuli similarly thereby strengthening our interpretation that older adults make greater errors due to reduced inhibitory mechanisms and not age differences in the confusability of stimuli.

*Method*

*Participants.* The sample consisted of 26 participants (12 younger adults, 14 older adults) recruited from undergraduate classes, and an existing participant registry established by the Adult Development and Aging laboratories through advertisements in community newspapers. The younger adults ranged in age from 18 to 33 years (M = 25.55, SD = 4.76), and the older adults ranged in age from 64 to 80 (M = 71.71, SD = 5.61). Exclusion criteria for both groups included the presence of any disease, health related disorder or use of medications that might alter cognitive status. Additionally, individuals that participated in the previously described study were excluded since it was important that the sample for this study have no prior knowledge of the sequences of steps in the SA paradigm.

The participants provided demographic and self-reported health information before testing. Table 1b shows the age, education, self-reported health, and gender of the participants as a function of age group. The older adults has significantly more years of education than the younger adults, $\underline{F}$ (1, 25) = 6.07, $\underline{p}$ = .02, $\eta^2$ = .21, and rated their health significantly worse, $\underline{F}$ (1, 25) = 6.29, $\underline{p}$ = .02, $\eta^2$ = .22.

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Insert Table 1b about here

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*Materials.* The computerized task was designed to garner independent ratings of visual similarity between the colour pictures used as targets and distractors in the previously described study. In the previously described study, there were three everyday activities (wrapping a gift, writing and mailing a letter, smoking a cigarette) that were comprised of a sequence of eight steps each. Each step was pictorially represented on the computer screen. Given that there were eight steps to each sequence, there are 28 possible pairings of each of the three everyday tasks. In sum total, the participants were asked to rate 84 pairs of pictures for their similarity (which was divided by task into 3 blocks of 28).

The paradigm was administered using a Macintosh G4, and programmed using SuperLab Pro 1.75 experimental generation software. The pairs of pictures were reduced in size to be presented side by side on the screen, with a similarity rating scale positioned directly below the picture set (see Appendix G for an example). All of the picture presentations were counterbalanced to ensure that each picture (e.g., Step 1, Step 2) appeared on both the left and right sides of the screen equally often. The picture pairs were presented for a maximum of 15 seconds in which the participant was instructed to rate the similarity between the pictures. If the participant did not respond to the stimulus before this time limit, the program would automatically proceed to the next pair of pictures to be rated.

*Procedure.* Participants first read and signed the consent form, and then filled out the demographic questionnaire. Next, individuals were seated in front of the computer to commence the visual similarity task. They were instructed to rate how similar each set of two pictures appeared on a scale of 1 to 5 (1 corresponding to 'very dissimilar' and 5 corresponding to 'very similar') by pressing the appropriately labeled button on a SuperLab RB-610 response box. The buttons were each numbered 1 to 5, and the last button was labeled 'next' in order to advance the screens. After completing all three blocks, participants were verbally debriefed as to the purpose of the study and any remaining questions were addressed.

*Results*

The primary purpose of this study was to investigate the visual similarity of the stimuli from the SA paradigm. The first set of analyses was carried out to examine whether visual similarity was directly related to the position of the target from the distractor (lag). Next, the issue of whether there were age group differences in visual similarity ratings, and whether this depended on the lag between items in a pair was addressed.

In order to determine whether there was a lag effect on visual similarity, the lag for each of the 84 pairs of pictures first had to be determined (see Appendix H). Afterwards, similarity ratings that participants had ascribed to the pairs were averaged according to their corresponding lags (across the 3 tasks), such that each participant had a mean value for Lags 1-7. The larger lags (5, 6, and 7) were collapsed into one category (here after referred to as Lag 5) as was done in the previous study in order to equalize the number of occurrences of the lags in each respective category. Table 8 summarizes the similarity means for Lags 1 to 5 as a function of age group.

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Insert Table 8 about here

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A mixed factorial ANOVA with Age Group (young, old) as the between subjects factor and Lag (Lags 1-5) varying within subjects was carried out using the mean similarity ratings to evaluate our main hypothesis. The results indicated a significant Lag main effect, $F(4, 21) = 27.92$, $p < .001$, $\eta^2 = .84$ due to substantially higher ratings of similarity for the lower lags compared to the higher lags. For example, paired samples t tests on the similarity ratings in Lags 1-5 indicated that similarity ratings were significantly higher in Lag 1 ($M = 3.20$, $SD = 0.61$) compared to Lag 5 ($M = 2.21$, $SD = 0.58$), $t(25) = 8.34$, $p<.001$. This suggests that on the previous study, participants could have made more errors the closer the distractor was to the target (forming an inverse U function) due to the visual similarity of the stimuli.

There was also a main effect of Age Group, $F(1, 24) = 4.18$, $p = .05$, $\eta^2 = .15$ such that the younger participants produced higher ratings of similarity ($M = 2.88$, $SD = .33$) than older participants ($M = 2.48$, $SD = .60$). The interaction between age group and lag position was not significant, $p = .20$ suggesting that the lag effect acted on both younger and older adults similarly. This indicated that the increased magnitude of error in SA performance for the older participants was not a result of increased confusability between the stimuli but likely a reflection of reduced memory or inhibitory processes.

An additional mixed factorial ANOVA with Age Group (young, old) as the between subjects factor and Pairing[11] (Pairings 1 to 28) and Task (wrapping a gift, writing a letter, smoking a cigarette) as the within subjects factors was carried out on the similarity ratings. The analysis was carried out to evaluate whether the specific pairings contributed to the lag effect across the three tasks or whether there were different pairs that were rated as similar across the tasks. The results indicated a marginally significant three way interaction between Task, Pairing and Age Group, $\underline{F}(54, 1296) = 1.62$, $\underline{p} = .07$, $\eta^2 = .06$.[12] Post hoc ANOVAs revealed that the Pairing X Age Group interaction was not significant within the first task (wrapping a gift), $\underline{p} = .11$, significant in the second task (writing and posting a letter), $\underline{F}(27, 648) = 1.95$, $\underline{p} = .04$, $\eta^2 = .09$, and marginally significant in the third task (smoking a cigarette), $\underline{F}(27, 648) = 1.83$, $\underline{p} = .07$, $\eta^2 = .07$. Despite efforts to control for visual similarity by equating features, this interaction seems to have resulted from a materials effect in which there were significant age group differences in confusability on "writing" and "smoking".

There was also a main effect associated with Pairing, $\underline{F}(27, 648) = 17.95$, $\underline{p} < .001$, $\eta^2 = .43$. The main effect associated with Age Group, $\underline{F}(1, 24) = 4.66$, $\underline{p} = .04$, $\eta^2 = .16$ indicated that younger participants rated pairs of pictures as more similar ($\underline{M} = 2.88$, $\underline{SD} = .33$) than the older participants ($\underline{M} = 2.48$, $\underline{SD} = .60$). Additionally, a significant main effect associated with Task, $\underline{F}(2, 48) = 6.34$, $\underline{p} = .004$, $\eta^2 = .21$ was observed. Paired samples t tests on the similarity ratings in Tasks 1-3 indicated that there was no significant difference in ratings between Task 1 and Task 2, $\underline{p} = .42$, but there were significant differences in similarity ratings between Tasks 1 and 3, $\underline{t}(20) = 2.63$, $\underline{p} = .02$,

[11] See Appendix H for Description of Pairing
[12] The original analysis could not be carried out so the univariate statistics were used as an estimate of effects for this set of analyses.

and Tasks 2 and 3, $t(20) = 2.46$, $p = .02$. Participants rated Task 1 the most similar ($M$ = 2.78, $SD = .67$), Task 2 the next ($M = 2.65$, $SD = .76$), and Task 3 as the least similar ($M$ = 2.30, $SD = .58$). There were also significant interactions between Pairing and Task, $F(54,1296) = 11.41$, $p < .001$, $\eta^2 = .01$; and Pairing and Group $F(27, 648) = 2.07$, $p = .03$, $\eta^2 = .08$. Descriptive statistics reveal that different pairings were rated as similar within each task. For example, mean level of ratings that exceeded 4.00 were pairs 8, 9, and 26 in Task 1, Pair 1 in Task 2, and Pairs 9, 10 and 28 in Task 3.

The Pairing X Task interaction was the most significant for our third hypothesis. We sought to evaluate whether or not the same pairs of pictures were rated similarly across the three tasks. The Pairing X Task interaction illustrated that while the visual similarity for each pairing number was significantly different from one another, this difference was dependent on the task at hand. For example, In Appendix A, Steps 7 and 8 in "smoking" were likely rated as more similar than Steps 7 and 8 in "wrapping". That is, the pairings of pictures were not rated similarly across the three tasks.

*Discussion*

The results of Experiment 1b provide a more detailed level of analysis of the SA paradigm by addressing the issue of visual similarity and age differences in investigating sequential behaviour. More specifically, in line with the concerns of Rünger (2002), we examined the visual similarity of the stimuli used in the main study in order to evaluate the potential contribution of visual similarity in the results of the main study. More specifically, we were interested in examining whether visual similarity contributed to the observed age group differences in intrusion errors, and the significant lag effect on intrusion errors (i.e. the inverse U function).

Firstly, we confirmed our hypothesis that lag position was indeed related to visual similarity ratings, in line with Rünger (2002). Visual similarity is a potential confound that needs to be addressed if claiming that responses to targets or distractors are solely a function of lag position. However, we believe that the investigation of naturalistic sequences inevitably implies that adjacent steps will be visually similar and therefore findings from any naturalistic study should take visual similarity into account. For example, Chow (2002) investigated sequential behaviour by using the SA paradigm with a sequence of smaller to larger animals. Instead of finding evidence for lateral inhibition, the reverse was found. Participants made more errors, the closer the distractors were to the targets because the closer in size the targets were, the more similar they were visually. For example, a fish may be more visually similar to a bird than to a zebra. This confusability may have contributed to the inverse U function found in this study as well as in the main study. We replicated the findings of Chow (2002) in that our participants made more intrusion errors the closer the relative lag position was to the target. These findings could be attributed to the visual similarity that has been illustrated between adjacent steps (smaller lags) thereby causing participants to confuse proximal distractors more than distal ones.

Having addressed the issue of visual similarity and lag position, as well as that of age differences in perception of similarity, we still wanted to examine whether or not the same stimuli contributed to the similarity ratings across the tasks. Because we had three independent tasks and sequences, we had the opportunity to evaluate whether or not ratings of the same pairs of pictures (pairings 1 to 28) contributed to smaller lag positions being the most visually similar. This particular analysis helped address the issue of whether the visual similarity of the stimuli explain the finding of greater errors in the Lag +1 condition as compared to the Lag -1 condition, demonstrating self-inhibition. Analyses revealing that different pairings across the three tasks contributed to the higher visual similarity rating of the Lag 1 position demonstrate that the increased errors in the Lag +1 condition is likely not a result of visual similarity but rather of the hypothesized inhibitory construct of self-inhibition.

An additional concern that we sought to address was that older adults were not differentially affected due to the similarity ratings of the targets and distractors. Because younger adults rated the picture pairings as more similar, and older adults made a greater number of intrusion errors in the main study it is unlikely that older adults were differentially penalized by the visual similarity between targets and distractors when performing the SA paradigm.

In sum, visual similarity is an important issue to address when examining sequential behaviour, and more specifically when looking at naturalistic sequences in sequential behaviour. Our study found that visual similarity likely contributed to performance on the SA paradigm. This finding was expected given that we were focusing on a naturalistic action sequence (which inevitably encompasses adjacent steps being visually similar) in order to increase the ecological validity of the paradigm. The tradeoff between ecological validity and internal validity is such that we had the inherent confound of visual similarity to address in our paradigm. The norming study substantiated the fact that both younger and older adults found adjacent steps more similar than those more distal from the target. Although visual similarity can be considered a limitation due to this finding, it should be noted that the usage of three tasks allowed us to uncover that different picture pairings across the tasks contributed to the higher ratings of visual similarity in smaller lag conditions than in larger ones. This further substantiates our findings in that the same U function was observed in all three tasks despite the different ratings of similarity for picture pairings.

Lastly, because our study focused on age differences in sequential behaviour, it was reassuring that our stimuli did not penalize older adults due to potential decline in visual acuity. In fact, younger adults rated pictures as being more similar than did older adults. This study illustrated that while visual similarity does factor into the SA paradigm, it does not account for all of the findings and when using the SA paradigm for naturalistic sequences, visual similarity must be addressed as a confounding variable. Additionally, one must consider whether visual similarity is the sole contributor to confusability between stimuli in order to fully ascertain the processes underlying sequential behaviour in the SA paradigm. Future investigations of sequential behaviour using the SA paradigm should include an examination of the visual similarity and/or confusability of the stimuli in order to better understand performance on the specific paradigm.

## Discussion

The main purpose of this study was to better understand the multifaceted nature of executive functioning. Firstly, the Sequential Action paradigm was administered to examine how inhibition, an executive control process, governs sequential performance. Findings from the SA paradigm revealed that self-inhibition propelled both younger and older adults through the sequences. As expected, older adults made more errors, and performed slower than younger adults. Older adults' performance improved significantly more than younger adults, suggesting the possibility that age associated decline in executive performance can be ameliorated with practice. Alternatively, it could be that practice automizes performance thereby reducing the need for executive control and not impacting executive performance per say.

Age differences in level of performance and intraindividual variability were then examined and compared across three neuropsychological measures of executive functioning, and the SA paradigm to further address the mixed findings on age associated decline in executive functions (Bryan & Luszcz, 2000). These analyses revealed age group differences in level of performance on only two of the three neuropsychological measures (Stroop Task, Visual Span Task) supporting the claim that neuropsychological tests of executive functioning can be unreliable in identifying age group differences in performance (Bryan & Luszcz, 2000; Salthouse, 2003). Intraindividual variability analysis of SA performance revealed that older adults were more variable than younger adults, in line with previous reports (e.g., Hultsch & MacDonald, 2004). Furthermore, different patterns of correlations between intraindividual variability and level of performance on measures of executive functioning for older and younger adults suggest that the relationship among executive component processes may be age dependent. For example, there were more significant positive intercorrelations among executive functioning measures in the younger adults than the older adults suggesting that older adults' cognitive abilities could be more differentiated than younger adults. This idea might contribute to the equivocal findings of age associated cognitive declines in executive functioning given that it is more difficult to observe consistent age-related decline with a differentiated construct. That is, given that studies use different measures of executive functioning (tapping into different facets of the construct), it is not surprising that the overall pattern of performance on executive functioning measures in younger adults is more stable than older adults.

The present results underscore the importance of investigating executive functioning in older adults for both neuropsychologists and cognitive aging theorists. For example, the construct of inhibition in older adults has been postulated as a central factor responsible for cognitive decline (Hasher & Zacks, 1988) and has been investigated in a number of different domains (e.g., Houghton, Glasspool, & Shallice, 1994; Li et al., 2000). Inhibitory processes are also linked to frontal lobe integrity (Rabbitt & Lowe, 2000) suggesting that the neuropsychological and cognitive experimental literatures can inform one another on this topic.

The current project directly linked two theoretical orientations by integrating an experimental sequential performance paradigm (Li et al., 2000) with the stimuli used to investigate Action Disorganization Syndrome in patient populations (Humphreys & Forde, 1998). By using the empirically derived stimuli from Humphreys and Forde

(1998), we increased the ecological validity of the SA paradigm (by using everyday tasks) while preserving the paradigm's analytic precision.

Additionally, we drew from both the neuropsychological and cognitive literature by measuring intraindividual variability in performance on the SA paradigm as an index of frontal lobe integrity (Bellgrove et al., 2004). This carefully controlled paradigm permitted an exhaustive examination of intraindividual variability in performance with over 300 data points per session, across three occasions. Additionally, within the confines of the SA paradigm, the impact of visual similarity on sequential performance was examined.

*Inhibitory Mechanisms in the SA Paradigm and Impact of Visual Similarity*

Consistent with previous findings across different sequences, the analyses of intrusion errors suggest that for both younger and older adults, there is evidence of self-inhibition (Chow, 2002; Li et al., 2000) and no evidence of lateral inhibition (similar to Chow, 2002). As a reminder, intrusion errors within the SA paradigm are hypothesized to represent steps available in an individual's working memory (i.e., sequence elements that are not suppressed). It is assumed that elements that are not suppressed might then trigger an intrusion error when the participant views a display related to that element.

As evidence for self-inhibition, both younger and older adults produced significantly more intrusion errors in the Lag +1 position than in the Lag -1 position. This finding lends support to the Competitive Queuing Architecture hypothesis (Houghton, 1990) by illustrating self-inhibition in both younger and older adults in a regular everyday sequence such as writing a letter. Repeated administrations of the SA paradigm reveal a differential impact of practice effects, such that older adults improved significantly more than younger adults across the three sessions and performed similarly to the younger adults by the last session. The slope indicating the difference in errors between Lag +1 and Lag -1 decreased to the same level as the younger adults by the third session suggesting a similar degree of inhibitory control in young and older adults. Alternatively, it is possible that older adults' memories were taxed more than younger participants in earlier sessions.

If older adults do show a greater degree of inhibitory control by the third session, the implication is that while older adults may have compromised inhibitory mechanisms that impair cognitive performance (in Hasher & Zacks, 1988, but see also Kramer et al., 1994; Maylor & Henson, 2000), they can benefit from practice and increase their inhibitory skills and in turn, their cognitive performance. This view is in line with Kramer, Hahn, and Gopher (1999) who demonstrated that with modest amounts of practice, older adults achieved similar switch costs on a task switching paradigm compared to their younger counterparts. Furthermore, their study suggests that older adults were only able to capitalize on practice sessions with low memory demands. This is similar to the SA paradigm in which the analysis of omission errors indicated that older adults' memory was not overly taxed, and the task was simply a measure of executive control processes. Convergent evidence for this assertion can be seen in the pattern of significant correlations between visual span measures and SA performance in younger adults, but not in older adults. If working memory capacity limitations were the reason for age deficits in SA performance, we should observe significant correlations between span and SA performance for this group.

Next, we did not find evidence of lateral inhibition as previously hypothesized to be found in Li et al., (2000). Instead, the present study extended the findings of Li et al., (2000) by using naturalistic stimuli, similar to Chow (2002). A unique feature of the present study is that empirically verified naturalistic sequences of behaviour were used from the neuropsychology literature. In both Chow (2002) and the present study, an inverse U function was observed in the intrusion errors such that participants made more intrusion errors for ordinally proximal distractors than for distal ones. There are a few possible accounts for these results. Firstly, in Chow (2002), in a post-test questionnaire, participants reported using a chunking strategy to remember the eight animal targets in the correct sequential order. This is more likely to occur in naturalistic sequences (e.g., steps to writing and posting a letter) than arbitrarily ordered sequences (e.g., Li et al., 2000) given the ease of chunking targets that are visually or semantically related to one another. This chunking would create more intrusion errors for adjacent steps than for proximal steps, assuming that all elements of a chunk are equally available to working memory until the chunk is carried out. Similar evidence for chunking in sequential performance is found in Logan (2004). The notion that chunking impacted sequential performance suggests that memory processes interact with executive control processes (i.e., inhibition) to change the pattern of performance. It may therefore be the case that the originally observed U-shaped, although attributed to lateral inhibition, should be more properly attributed to memory-related factors (e.g., element similarity, amenability to chunking).

An additional methodological difference to consider is that Chow (2002) and the present study used only exemplars of a specified order of steps or size ranking of animals.

Conversely, Li et al. (2000) asked their participants to memorize an order of random categories, and they were then asked to respond to exemplars of the categories during the computerized portion of the task. That being said, Dupuis, Li, and Ward (2005) observed a similar inverse U function to the present study using animal names in a similar hierarchical structure to that of Li et al. (2000). Therefore, it does not appear that the hierarchical structuring is the sole cause of the inversion of the U function.

Lastly, as per Rünger's (2002) suggestion, the visual similarity of the stimuli was investigated (Expt. 1b) to examine the potential contribution it had on our main findings. This companion study helped discern whether the pattern of intrusion errors was an artifact of visual similarity of adjacent distractors. We found that both age groups rated adjacent steps as more visually similar than non adjacent steps. This finding could be responsible for participants making more intrusion errors with proximal distractors as compared with more distal ones. That is, the inverse U function could have been produced as an artifact of visual similarity as opposed to the distractor's lag position in the sequence. While the notion of visual similarity is clearly important to consider when analyzing intrusion errors, it is also a by-product of using naturalistic sequences in the examination of sequential behaviour. Using naturalistic sequences in which the visual similarity of the distractors is systematically varied may be a way to distinguish the contributions of lateral inhibition and visual similarity.

This being said, if the visual similarity of the proximal targets accounts for the pattern of intrusion errors, it would lend support to the HT model of sequential action performance (Houghton & Tipper, 1994). Houghton's contention is that when there is a match between one's mental description of an item and stimulus input, there is activation.

That would explain intrusion errors based on visual similarity as opposed to relative lag position. [keep in mind that the HT model is also consistent with the original view that those steps that are 'available' in WM are likely to trigger a response when the stimulus matches – e.g., anticipatory +1 errors] This possibility further emphasizes the need for future studies of sequential behaviour to account for the effects of visual similarity and other potential modalities of similarity. For example, one could examine visual similarity by using randomly ordered categories and manipulate the order of the stimuli across participants to examine the impact of visual similarity on performance. Presumably, if visual similarity has a strong influence on lag error rates, then the most confusable pairs of stimuli would cause high rates of intrusion irrespective of their lag position.

*Relationship of Neuropsychological Measures to SA Performance*

In line with other findings, both Stroop (Bryan & Luszcz, 2000; Cohn, Dustman, & Bradford, 1984) and Visual Span (Bryan & Luszcz, 2000) yielded significant age group differences favouring younger adults on the Stroop task and the Visual Span task. More specifically, younger adults inhibited over-learned responses on the Stroop task thereby reading the words from the "colour-word" condition faster than older adults relative to participants' baseline performances on the "colour" condition. In the Visual Span test, younger adults were able to remember and point to longer spans than the older adults in both the forward and backward conditions.

Contrary to previous findings (Van der Linden, Beerten & Pesenti, 1998) there were no age group differences on the Random Generation Task. One possibility that could account for this finding is the effect of speed of processing in older adults' cognitive functioning (Salthouse, 1996). In the present study, participants were not required to emit responses at a fixed rate; they rather had a total time limit to generate as many letters as possible in a randomized order. It is possible that this method reduced the demand on the participants' speed of processing thereby eliminating any age differences in performance on Random Generation (see Fisk & Warr, 1996 for a similar argument). More specifically, it is possible that older adults had sufficient time to inhibit over-learned responses (e.g. alphabetic stereotypes) at a similar rate to younger adults.

Also notable were the age related differences in the relationship between the neuropsychological measures and the SA paradigm. For the younger adults, performance on the Stroop task and the Visual Span task were positively correlated, and level of performance on the SA paradigm (i.e., percentage of intrusion errors made) was positively correlated with the Visual Span task. These correlations indicated that higher levels of inhibitory control on one task were related to higher levels of inhibitory control on other tasks.

Interestingly, for older adults, there were no significant correlations in performance between the neuropsychological measures of executive functioning and the SA paradigm. If one were to look at only the correlational results with the level of performance data it would appear that speaking of executive functioning or even inhibition as a unitary construct is very misleading for older adults. There is no evidence of shared variance between the measures of executive functioning used in this study. There are a number of possibilities that may account for this finding. Firstly, it is possible that the differing temporal demands on the subjects themselves differentially impacted performance. In the Stroop task, older adults were measured on the speed with which they successfully inhibited over-learned responses (i.e. word reading).

Conversely, on the Visual Span test, older adults had no external demands on the speed of their responses (or inhibitory actions) thereby potentially affecting their cognitive performance differently. That is, while inhibition or executive functioning is a viable construct to examine on its own, it may be necessary in future studies to equate tasks on their temporal demands in order to examine age differences in executive functions independent of speed of processing (Salthouse, 1996). Another possibility is to use speed of processing as a covariate variable while analyzing executive functioning.

A second way to explain the lack of shared variance in measures of executive functioning among the olde adults is to consider the level of complexity within the given tasks. More specifically, perhaps measuring inhibition in sequential behaviour is not equivalent to measuring inhibition on the Stroop task thereby precluding significant correlations (Miyake et al., 2000). Lastly, tests of executive function yield more ambiguous age related differences than they do with neuropsychological patients (Bryan & Luszcz, 2000) because executive functioning does not exhibit the same amount of shared variance across tasks in older adults.

*Intraindividual Variability in Executive Functioning Measures*

In line with other findings (Christensen et al., 1999; Hultsch et al., 2000; S.-C. Li & Lindenberger, 1999; Williams, Hultsch, Strauss, Hunter, & Tannock, 2005) the present results illustrate that older adults are more variable than younger adults on SA response latencies, both within Session 1 and across three sessions. On Stroop, Visual Span and Random Generation, there were no significant age group differences in intraindividual variability within each task. This finding likely reflects the number of data points from which variability measures were extracted. That is, on the three neuropsychological measures, there were fewer data points than on the SA paradigm and therefore less room for individuals to vary from response to response. For this reason, it is premature to conclude that variability in neuropsychological measures of executive functions are completely unrelated on the basis of the present findings. However, data from the SA paradigm, in which individuals generated at least 300 data points per session, multiplied by three sessions, provide more convergent support.

A related question to consider is whether variability on one measure is correlated with variability on another measure. Some evidence suggests that intraindividual variability correlates across tasks (Hultsch et al., 2000) while other studies suggest that variability can vary according to task demands for executive control (e.g., West et al., 2002). Additionally, Allaire and Marsiske (2005) suggest that there are two types of variability; adaptive and maladaptive intraindividual variability. In their study, intraindividual variability was not strongly correlated across the three cognitive tasks, but was correlated within a task. Furthermore, they observed positive correlations between level of variability and the magnitude of a person's practice related gain on a particular measure. They refer to this variability as adaptive intraindividual variability given the positive association with level of performance. Allaire and Marsiske (2005) suggest that the reason the literature is divided as to whether variability is correlated across tasks is because of the two different types of variability. Maladaptive intraindividual variability which is typically observed for (non cognitive) reaction time based tasks is unlikely to show substantial growth or improvement across sessions. Conversely, adaptive intraindividual variability is more often observed for cognitive tasks in which individuals show improvement as a function of repeated assessments and may reflect individuals' active testing of new performance strategies.

In this study, there were significant positive correlations between variability on the Stroop Test and variability on the Visual Span test and there were significant positive correlations between the SA paradigm, and the Stroop task indicating that the more variable older adults were on one task, the more variable they were on the others. It is difficult to discern which tasks showed maladaptive versus adaptive variability with the exception of the Random Generation Task that could have possibly showed adaptive variability given the necessity of variable strategies to be successful in the task, and the negative correlation between Random Generation variability and the SA paradigm.

*The relationship between intraindividual variability and level of performance on executive measures.* Interestingly, for both younger and older adults, there were significant positive correlations between level of performance on the SA paradigm (as measured by percentage of intrusion errors, and percentage of omission errors), and intraindividual variability in RT both within session one, and across sessions. These correlations suggest that the more intrusion and omission errors individuals made, the more variable they were on RT measures to target steps (Rs ranged from .51 to .77, cf. Allaire & Marsiske, 2005). These correlations were independent of level of performance given the purification procedure before the analyses were performed.

This finding adds to the available evidence that intraindividual variability is a marker of frontal brain pathology (e.g., Bellgrove et al., 2004; Stuss et al., 2003). For example, Bellgrove et al. (2004) used event-related functional magnetic resonance imaging to investigate how the functional neuroanatomy of executive control is related to performance variability on a Go/No-go inhibition paradigm. They demonstrated that decreased variability on the paradigm was a strong predictor of inhibitory success, and relates to brain activation in the frontal regions. More specifically, increased variability on their task was associated with increased frontal activation for less successful individuals, likely reflecting the greater demand for executive control in order to maintain task performance. Additional research has examined intraindividual variability in performance from a neurobiological level in order to better understand age differences in executive functioning. For example, S.-C. Li et al., 2001 suggest that the observed age-related increases in intraindividual variability and decreases in cognitive functions could be related to compromised neuronal mechanisms (i.e., age-related decline in dopaminergic functioning).

For the present results to fully complement these other published findings, intraindividual variability in reaction times should correlate with level of performance in all measures examining inhibitory or executive processes. Instead, there were only modest correlations indicating that the worse an individual performed on a given task, the more variable they were in their responses across sessions. There was one finding that did not yield the expected negative relationship between intraindividual variability and level of performance. In the Random Generation Task, participants were *more* variable when they generated more responses. It is possible that because the participants were not required to produce speeded responses (similar to Van der Linden et al., 1998), were able to creatively activate different strategies that would yield randomized alphabetic letters. This is supported by anecdotal reports of strategy use (e.g., remembering the first letter of all family members' names and then proceeding to the second letter). Furthermore, this finding is supported in the developmental research which suggests that activating new performance strategies is associated with increased intraindividual variability, and successful performance on a given cognitive task (for review see Allaire & Marsiske, 2005).

On a related note, it is conceivable that in the current study, participants who had the least inhibitory control also relied the most on strategic methods to perform successfully in the Random Generation task instead of using inhibitory processes. This could account for the inverse relationship between intraindividual variability and level of performance in the Random Generation task as well as the absence of age differences in level of performance in the Random Generation task. Future studies on the Random Generation task should examine the relationship between specific strategies used and level of inhibitory control (measured with other tasks), as well as the effects of temporal constraints on older and younger adults.

*Understanding the Construct of Executive Functioning*

The literature is equivocal as to the definition of executive functioning let alone whether there are age differences therein (e.g., Rabbitt & Lowe, 2000). A major issue under consideration is whether it is comprised of distinct subsystems or whether all of these subsystems fall under an identical system architecture that governs all executive functioning (Rabbitt & Lowe, 2000; Wecker et al., 2000). The present study focused on inhibition in an experimental paradigm and whether inhibitory control in sequential behaviour is related to performance on neuropsychological tests of executive functioning. This study is in line with Wecker et al., (2000), who emphasized the importance of partialling out the components in the assessment of multidimensional cognitive tasks (such as sequential behaviour). The absence of uniformly significant correlations in level of performance across all measures support the idea that executive functioning is likely comprised of distinct subsystems that are related to executive performance. The current results demonstrate that inhibitory control is a unique construct that contributes to some but not all executive functions.

To evaluate the structure of executive functioning and possible developmental changes therein, the intercorrelations among tasks were evaluated separately for younger and older adults. These analyses revealed different patterns of correlations for executive measures in younger and older adults, and suggest that executive functioning may be more unitary for young adults than for older adults. In the same vein, it is possible that the differences between frontal pathology in patients and in healthy older adults are qualitative and not quantitiative in nature. While this is contrary to many findings illustrating that executive functioning is a multifaceted construct for all adults (e.g., Miyake et al., 2001; Salthouse et al., 2003), this developmental shift could also account for some of the uncertainty in describing executive functioning in older adults (e.g., Bryan & Luszcz, 2000). More specifically, researchers have reported inconsistent age effects on conceptually similar paradigms (for review see Rabbitt, 2003). For example, investigators have found mixed evidence of age-related increases in perseverative errors on the Wisconsin Card Sorting Test (e.g., Daigneault et al., 1992; cf. Boone, Miller, Lesser, Hill, & D'Elia, 1990).

This inconsistency may be partly attributable to the use of neuropsychological tests that have limited sensitivity when used with sub-clinical populations (Bryan & Luszcz, 2000). The present study addressed Bryan and Luszcz's concern by using a combination of an age-sensitive experimental paradigm and related neuropsychological measures of executive functioning. Despite this improvement in sensitivity, the present results showed age differences in the structure of executive functioning, thus providing more solid support for this argument.

To understand executive behaviour as it relates to the frontal lobe hypothesis of aging, intraindividual variability in performance was examined due to its association with frontal lobe vulnerability in the literature (Stuss et al., 2003). Within each task, a positive correlation between performance level and intraindividual variability on the same task would be supportive of this vulnerability argument. Indeed, the observed significant correlations for both younger and older adults between level of performance and their respective measures of intraindividual variability are consistent with such claims (e.g., Bellgrove et al., 2004; West, 2003). A further step is to examine the intercorrelations of intraindividual variability across tasks, assuming that if variability is associated with vulnerability, a unitary model of executive functioning would be reflected in intraindividual variability correlating across different executive tests. This simple model of executive functioning was not supported. Instead, only specific pairs of tasks were significantly related in terms of intraindividual variability measures, and the pairs differed across age groups. These results therefore echo earlier conclusions that executive functioning is a multi-dimensional construct that varies in structure with aging.

A final issue related to the construct of executive functioning concerns the benefits of repeated testing. In the present study, older adults benefited from practice across sessions in the SA paradigm, performing like young adults by Session 3. This pattern underscores the need to consider age differences at different stages of learning (e.g., acquisition versus stable performance). The inconsistency in age-related findings noted earlier may be influenced by differences in task familiarity.

*Summary*

The present study is novel in its attempt to gain a finer understanding of the processes that govern sequential behaviour using a fusion of neuropsychological and experimental techniques. More specifically, we have extended neural network models of sequential action regulation (e.g., Hougton & Tipper, 1996; Houghton, 1990) by using a paradigm that merges cognitive methodology (e.g., Li et al., 2000) with the neuropsychological measurement of everyday sequential behaviour (e.g., Humphreys & Forde, 1998). An additional contribution of the present work is the consideration of intraindividual variability in relation to mean level of performance scores, and in relation to performance across tasks. Such a design allowed for the evaluation of hypotheses about aging, inhibition in sequential performance, frontal lobe integrity, and the structure of executive functioning in general.

The present findings suggest that executive functioning is a multifaceted construct, and that inhibition plays a central role in executive behaviour. More specifically, the results of this study demonstrated that self inhibitory mechanisms govern sequential performance in addition to the effects of visual similarity between stimuli. The follow-up study indicated that older adults' SA performance (more intrusions and omissions than young adults) could not be completely accounted for by visual similarity. Furthermore, visual similarity is not solely responsible for the age-differential benefits of practice that were observed in the SA data.

Further research is needed to assess the impact that visual similarity has on inhibition in sequential action in order to speak to the dissociability of self-inhibition from lateral inhibition, and to continue to examine the generalizability of inhibitory theories to ecological contexts and neuropsychological populations (e.g., Humphreys & Forde, 1998).

Additionally, the present findings underscore the importance of examining both intraindividual variability and level of performance in executive measures in older and younger adults. This focus could help us better understand the multidimensional structure of executive functioning (including intraindividual variability) and how they may change across adulthood. Perhaps the first step is to conduct cross sectional studies to provide cross validation of the present findings. Further research could also examine whether intraindividual variability in executive measures is task dependent, and how variability on a broader range of executive tasks correlates with various tests of executive functioning. The examination of intraindividual variability in this study underscores the need to further dissociate the different types of variability as a function of task and temporal demands in order to better understand which type of intraindividual variability may represent age associated vulnerability, and which represents successful cognitive performance. This would help us better understand not only executive functioning, but also age differences that exist therein.

This study addresses the more global concern plaguing researchers and clinicians alike: why do adults experience a decline in cognitive functioning as they grow older? There are many theories that attempt to address this question (Inhibitory Deficit Hypothesis: Hasher & Zacks, 1988; Executive Decline Hypothesis: Troyer, Graves &

Cullum, 1994) all of which relate to the idea that the frontal lobes deteriorate as we grow older (see Bench et al., 1993, relating inhibition to the frontal lobes). The assumption made is that if there is frontal lobe compromise in older adults then any cognitive functions associated with the frontal lobes must also deteriorate as we grow older. Based on this assumption, we examined executive functioning and its relationship to inhibition, and intraindividual variability in performance. While all three of these constructs have shown frontal involvement (Bellgrove et al., 2004; Stuss & Alexander, 2000; Stuss et al., 2003), they are not all correlated with one another. More specifically, level of performance across tests did not correlate significantly in older adults and only modest correlations were found in younger adults. This pattern supports the notion that executive functioning is a multifaceted construct (e.g., Salthouse et al., 2003), and suggests that the multidimensional structure may change with normal aging.

Furthermore, the pattern of intercorrelations between intraindividual variability in executive performance and level of performance points to the need to address both methods of examination when trying to discern an individual's level of executive functioning. Related to this point, future studies should continue to include a broad enough sampling of neuropsychological tests so as to have more than one test with a sufficient number of data points to investigate the relationship between variability in performance across tests (e.g., Salthouse et al. 2003). Additionally, in line with Allaire and Marsiske (2005), future studies should include tests that have varying degrees of cognitive components, and varying reliance of reaction time based measures.

*Conclusions*

Because we merged test methodology from neuropsychological and cognitive literatures, and considered interindividual variability together with mean performance levels, several conclusions can be drawn. In line with predictions, younger and older adults appear to use self-inhibition to regulate their sequential performance, given sufficient experience with the task. The observed improvement in older adults' SA performance may be due to the use of naturalistic materials in this study. Also consistent with predictions, intraindividual variability was negatively correlated with performance levels within most tasks. Where the relationship was reversed, variability may be attributable to increased exploration with new strategies. Finally, the present results do not support a global view of executive functioning, but instead indicate that executive functioning is multidimensional and that its structure changes as a function of normative aging.

Table 1.

*Demographic and Performance Characteristics as a Function of Age Group in Experiment 1*

| | | Age Group | |
|---|---|---|---|
| | | Younger Adults | Older Adults |
| Variables | | n = 23 | n = 20 |
| Age | M | 25.17 | 66.60 |
| | SD | 4.92 | 5.59 |
| Education[1] | M | 15.17 | 15.95 |
| | SD | 1.37 | 3.83 |
| Health[2] | M | 4.57 | 4.25 |
| | SD | 0.66 | 0.64 |
| Digit Symbol | M | 69.43 | 48.60 |
| | SD | 11.47 | 16.17 |
| % Female | M | 52.20 | 65.00 |
| | SD | -- | -- |

[1] Self-report of number of years of formal education completed
[2] Self-rating on a scale from 1 (poor) to 5 (excellent)

Table 1b.

*Demographic Characteristics as a Function of Age Group in Experiment 1b*

| | | Age Group | |
|---|---|---|---|
| | | Younger Adults[1] | Older Adults |
| Variables | | n = 11 | n = 14 |
| Age | M | 25.55 | 71.71 |
| | SD | 4.76 | 5.61 |
| Education[2] | M | 13.91 | 17.00 |
| | SD | 3.33 | 2.94 |
| Health[3] | M | 4.09 | 3.36 |
| | SD | 0.70 | 0.75 |
| % Female | M | 54.50 | 64.30 |
| | SD | -- | -- |

[1] Demographic data are missing for one younger adult.
[2] Self-report of number of years of formal education completed
[3] Self-rating on a scale from 1 (poor) to 5 (excellent)

Table 2.

*Percentage of Omission Errors in "writing and posting a letter" for Participants in Sessions 1, 2, and 3*

| | | Session | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Younger Adults | M | 3.52 | 1.91 | 1.71 |
| | n | 22 | 22 | 22 |
| | SD | 2.39 | 1.48 | 1.43 |
| Older Adults | M | 8.50 | 3.99 | 2.74 |
| | n | 20 | 20 | 20 |
| | SD | 6.43 | 3.53 | 3.17 |

Table 3.

*Percentage of Intrusion Errors across Lag Bins for "writing and posting a letter" in Sessions 1, 2 and 3.*

| | | Lag | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ≤-5 | -4 | -3 | -2 | -1 | +1 | +2 | +3 | +4 | ≥+5 |
| | | | | | | Session 1 | | | | | |
| Young | M | 0.59 | 1.66 | 0.88 | 2.56 | 4.32 | 15.25 | 2.22 | 2.61 | 0.70 | 0.76 |
| n = 22 | SD | 1.27 | 3.31 | 1.78 | 4.33 | 5.88 | 8.92 | 3.21 | 4.96 | 1.93 | 2.45 |
| Old | M | 1.12 | 2.76 | 1.46 | 4.81 | 5.56 | 25.04 | 5.84 | 5.34 | 2.57 | 1.45 |
| n = 20 | SD | 1.89 | 4.84 | 2.88 | 5.02 | 4.64 | 13.89 | 5.64 | 8.06 | 4.13 | 2.66 |
| | | | | | | Session 2 | | | | | |
| Young | M | 0.38 | 1.77 | 1.41 | 1.88 | 2.22 | 10.06 | 2.35 | 0.69 | 1.07 | 0.73 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| n = 22 | SD | 1.30 | 3.59 | 5.18 | 3.36 | 2.99 | 7.20 | 5.13 | 1.60 | 2.95 | 2.21 |
| Old | M | 0.84 | 0.83 | 0.86 | 1.46 | 2.00 | 16.55 | 2.26 | 1.84 | 3.29 | 1.13 |
| n = 20 | SD | 1.61 | 2.71 | 1.90 | 2.79 | 2.38 | 10.49 | 3.99 | 3.75 | 5.38 | 3.01 |
| Session 3 | | | | | | | | | | | |
| Young | M | 0.76 | 2.53 | 0.94 | 2.22 | 2.22 | 9.96 | 1.69 | 0.96 | 1.07 | 0.73 |
| n = 22 | SD | 2.13 | 4.45 | 3.04 | 3.44 | 2.83 | 10.10 | 3.71 | 2.71 | 2.95 | 2.80 |
| Old | M | 0.42 | 0.85 | 0.52 | 0.85 | 1.33 | 9.38 | 1.86 | 0.30 | 1.18 | 1.29 |
| n = 20 | SD | 1.02 | 2.08 | 1.69 | 1.98 | 1.96 | 5.88 | 4.47 | 0.93 | 2.41 | 3.38 |

Table 4.

*Percentage of Intrusion Errors across Lag Bins for "wrapping a gift" and "smoking a cigarette"*

| | | Lag | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ≤-5 | -4 | -3 | -2 | -1 | +1 | +2 | +3 | +4 | ≥+5 |
| | | | | | | Wrapping a Gift | | | | | |
| Young | M | 0.76 | 0.51 | 1.10 | 2.22 | 1.32 | 12.77 | 6.53 | 2.22 | 1.34 | 0.44 |
| n = 20 | SD | 1.75 | 1.63 | 1.96 | 3.10 | 2.15 | 11.37 | 6.69 | 3.53 | 6.27 | 1.13 |
| Old | M | 0.76 | 0.51 | 1.10 | 2.22 | 2.45 | 18.94 | 6.53 | 2.22 | 1.34 | 0.44 |
| n = 22 | SD | 1.75 | 1.63 | 1.96 | 3.10 | 3.38 | 11.17 | 6.69 | 3.53 | 6.27 | 1.13 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Smoking a Cigarette | | | | | |
| Young | M | 0.65 | 4.55 | 1.72 | 2.01 | 4.55 | 8.06 | 3.38 | 4.41 | 1.07 | 1.14 |
| n = 20 | SD | 1.51 | 5.85 | 2.55 | 3.40 | 4.77 | 7.38 | 4.01 | 3.59 | 3.91 | 2.06 |
| Old | M | 0.86 | 3.61 | 3.63 | 2.21 | 5.46 | 9.09 | 3.00 | 3.19 | 0.59 | 0.56 |
| n = 22 | SD | 1.63 | 4.86 | 4.11 | 2.74 | 3.99 | 5.83 | 3.72 | 3.34 | 1.81 | 1.14 |

Table 5a.

*Correlations Between Level of Performance and Intraindividual Variability in the Neuropsychological Measures and the SA Paradigm for Younger Adults*

| | Task | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Paradigm (Omissions and Intrusions) | | | | Stroop | | Random Generation | | Visual Span (Forward and Backward) | | | |
| | O1 | OS | Int1 | IntS | S1 | SS | Rgt1 | RgtS | F1 | FS | B1 | BS |
| O1 | - | | | | | | | | | | | |
| OS | .95** | - | | | | | | | | | | |
| Int1 | .75** | .81** | - | | | | | | | | | |
| IntS | .80** | .90** | .90** | - | | | | | | | | |
| S1 | .06 | -.07 | -.08 | -.15 | - | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | .36 | .25 | .33 | .24 | .87** | - | | | | | | |
| Rgt1 | .31 | -.31 | -.27 | -.28 | -.14 | .09 | - | | | | | |
| RgtS | -.24 | -.16 | -.12 | .02 | .18 | .13 | .89** | - | | | | |
| F1 | -.43* | -.39 | -.43* | -.30 | .25 | .16 | .24 | .36 | - | | | |
| FS | -.54** | -.53** | -.47* | -.38 | -.12 | -.20 | .16 | .19 | .82** | - | | |
| B1 | -.47* | -.47* | -.49* | -.50* | .16 | .05 | .11 | .10 | .70** | .62** | - | |
| BS | -.65** | -.61** | -.62** | -.60** | .004 | -.16 | .20 | .23 | .76** | .75** | .83** | - |
| SA | | | | | | | | | | | | |
| Paradigm | .76** | .76** | .64** | .67** | -.06 | .21 | -.27 | -.10 | -.15 | -.23 | -.29 | -.39 |
| RT1ISD | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA | | | | | | | | | | | | |
| Paradigm RTSISD | .64** | .67** | .45* | .54** | -.12 | .07 | -.13 | .004 | -.05 | -.19 | -.25 | -.22 |
| SISD | .42 | .32 | .17 | .16 | .63** | .71** | -.21 | -.05 | .09 | -.21 | .18 | -.003 |
| RgtISD | .02 | .04 | .10 | .12 | .31 | .18 | .30 | .50* | .18 | .04 | .17 | .14 |
| FISD | .19 | .08 | -.07 | -.07 | .15 | .10 | -.03 | -.20 | -.34 | -.24 | .01 | -.23 |
| BISD | .15 | .16 | .06 | .15 | .59** | .54** | .25 | -.34 | .09 | -.11 | -.08 | -.05 |

*Note.* The Suffix "1" indicates that it is the first session data. The Suffix "S" indicates that the data was averaged across the 3 sessions.
The Suffix "ISD" indicates that intraindividual standard deviations were used.
Intraindividual Standard Deviations for the SA paradigm were calculated from reaction times to sequential target pictures.
* $p < .05$
** $p < .01$

Table 5b.

*Correlations Between Level of Performance and Intraindividual Variability in the Neuropsychological Measures and the SA Paradigm for Older Adults*

| | Task | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SA Paradigm (Omissions and Intrusions) | | | | Stroop | | Random Generation | | Visual Span (Forward and Backward) | | | |
| | O1 | OS | Int1 | IntS | S1 | SS | Rgt1 | RgtS | F1 | FS | B1 | BS |
| O1 | - | | | | | | | | | | | |
| OS | .94** | - | | | | | | | | | | |
| Int1 | .50* | .41 | - | | | | | | | | | |
| IntS | .58* | .51* | .94** | - | | | | | | | | |
| S1 | -.06 | -.09 | -.09 | -.23 | - | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SS | .11 | .09 | .05 | -.11 | .92** | - | | | | | | |
| Rgt1 | -.12 | -.07 | -.39 | -.31 | .18 | .20 | - | | | | | |
| RgtS | -.12 | -.10 | -.31 | -.26 | .21 | .21 | .91 | - | | | | |
| F1 | -.10 | .08 | -.14 | -.19 | .17 | .02 | .15 | .10 | - | | | |
| FS | -.18 | -.02 | -.30 | -.36 | .11 | -.04 | .18 | .06 | .91** | - | | |
| B1 | -.09 | .07 | -.18 | -.06 | .14 | .09 | .36 | .33 | .23 | .21 | - | |
| BS | -.36 | -.16 | -.36 | -.25 | .18 | -.003 | .28 | .26 | .48* | .42 | .84** | - |
| SA | | | | | | | | | | | | |
| Paradigm | .74 | .61** | .66** | .62** | .22 | .30 | -.37 | -.34 | -.17 | -.28 | -.26 | -.40 |
| RT1ISD | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SA | | | | | | | | | | | | |
| Paradigm | .77** | .73** | .52* | .55* | .08 | .17 | -.36 | -.29 | -.06 | -.21 | -.16 | -.27 |
| RTSISD | | | | | | | | | | | | |
| SISD | .41 | .30 | .03 | .01 | .72** | .72** | .25 | .19 | -.13 | -.12 | .05 | -.06 |
| RgtISD | -.40 | -.31 | -.47* | -.49* | .36 | .34 | .49* | .65** | .19 | .20 | .48* | .45* |
| FISD | .28 | .29 | .46* | .41 | .08 | .14 | -.18 | .14 | .14 | .14 | -.12 | -.16 |
| BISD | -.24 | -.30 | -.11 | -.15 | -.13 | -.18 | -.18 | -.11 | -.15 | -.24 | -.63** | -.31 |

*Note.* The Suffix "1" indicates that it is the first session data. The Suffix "S" indicates that the data was averaged across the 3 sessions.
The Suffix "ISD" indicates that intraindividual standard deviations were used.
Intraindividual Standard Deviations for the SA paradigm were calculated from reaction times to sequential target pictures.
* $p < .05$
** $p < .01$

Table 6.

*Mean Reaction Time Measures on "Writing and Posting a Letter" of the SA Paradigm as a Function of Session and Age Group*

| | | Session | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Young | M | 521 | 494 | 494 |
| | SD | 156 | 132 | 129 |
| Old | M | 623 | 564 | 542 |
| | SD | 193 | 154 | 124 |

Table 7a.

*Intercorrelations Between Intraindividual Variability on the Neuropsychological Measures and the SA Paradigm for Younger Adults*

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | SA Paradigm (Reaction Times) | | Stroop | Random Generation | Visual Span | |
| | RT1ISD | RTSISD | SISD | RgtISD | FISD | BISD |
| RT1ISD | - | | | | | |
| RTSISD | .86** | - | | | | |
| SISD | .06 | .04 | - | | | |
| RgtISD | .28 | .13 | .16 | - | | |
| FISD | -.14 | -.22 | .34 | -.23 | - | |
| BISD | -.003 | .11 | .21 | .21 | .22 | - |

*Note*. The Suffix "1" indicates that it is the first session data. The Suffix "S" indicates that the data was averaged across the 3 sessions.
The Suffix "ISD" indicates that intraindividual standard deviations were used.
* $\underline{p} < .05$
** $\underline{p} < .01$

Table 7b.

*Intercorrelations Between Intraindividual Variability on the Neuropsychological Measures and the SA Paradigm for Older Adults*

| | Task | | | | | |
|---|---|---|---|---|---|---|
| | SA Paradigm (Reaction Times) | | Stroop | Random Generation | Visual Span | |
| | RT1ISD | RTSISD | SISD | RgtISD | FISD | BISD |
| RT1ISD | - | | | | | |
| RTSISD | .90** | - | | | | |
| SISD | .48** | .36 | - | | | |
| RgtISD | -.47* | -.37 | .02 | - | | |
| FISD | .16 | .05 | .09 | -.34 | - | |
| BISD | .04 | .08 | .46* | -.25 | -.26 | - |

*Note*. The Suffix "1" indicates that it is the first session data. The Suffix "S" indicates that the data was averaged across the 3 sessions.
The Suffix "ISD" indicates that intraindividual standard deviations were used.
* $\underline{p} < .05$
** $\underline{p} < .01$

Table 8.

*Mean Similarity Ratings for Lag Pairs as a Function of Age in Experiment 1b*

| | | Lag[1] | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Young | M | 3.56 | 3.08 | 2.78 | 2.69 | 2.29 |
| n = 12 | SD | 0.42 | 0.43 | 0.34 | 0.51 | 0.51 |
| Old | M | 2.90 | 2.62 | 2.36 | 2.39 | 2.14 |
| n = 14 | SD | 0.59 | 0.63 | 0.66 | 0.60 | 0.65 |

[1] Similarity ratings on a scale of 1 (dissimilar) to 5 (very similar)

Figure 1.

*Intrusion Error Rates by Age and Lag Position for "writing and posting a letter" across sessions*

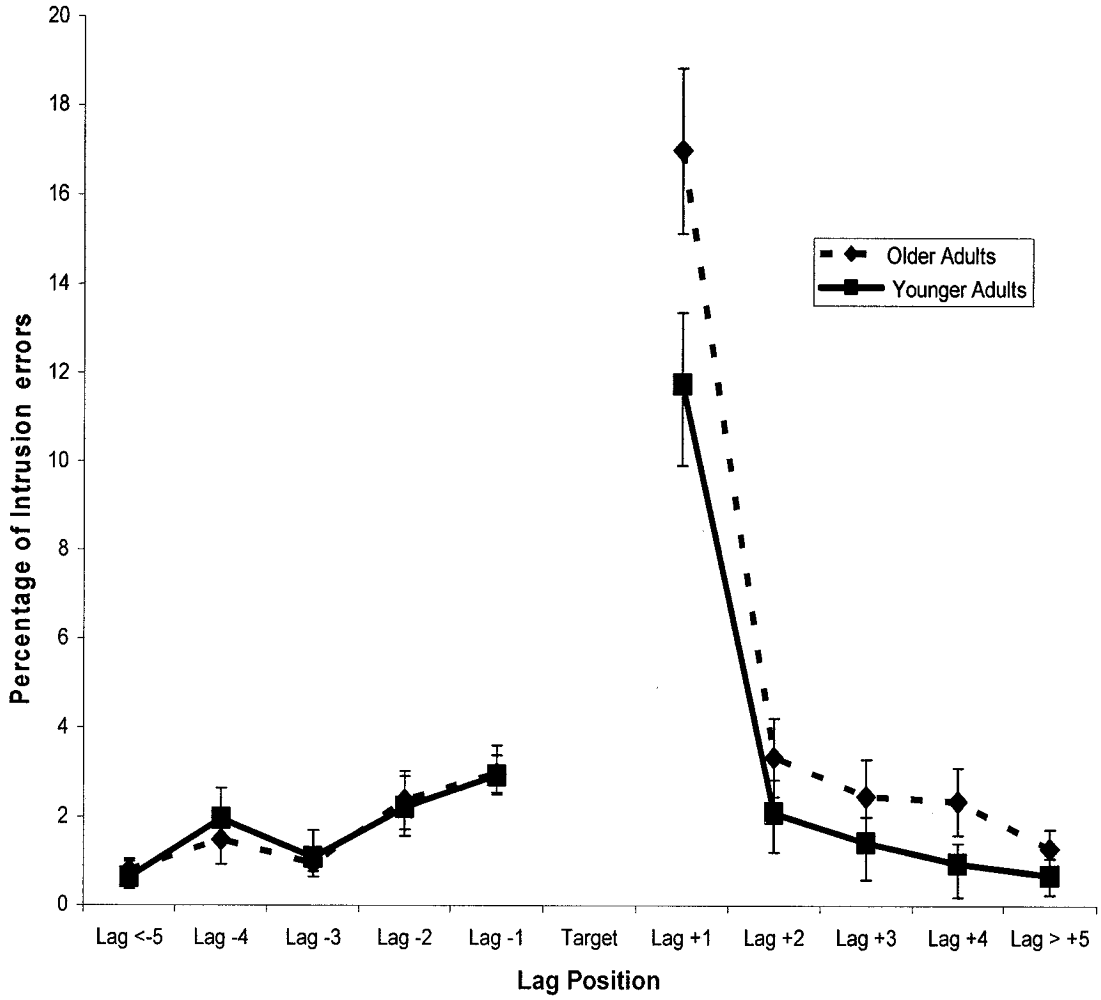


Figure 2.

*Intrusion Error Rates by Age and Lag Position for "wrapping a gift"*

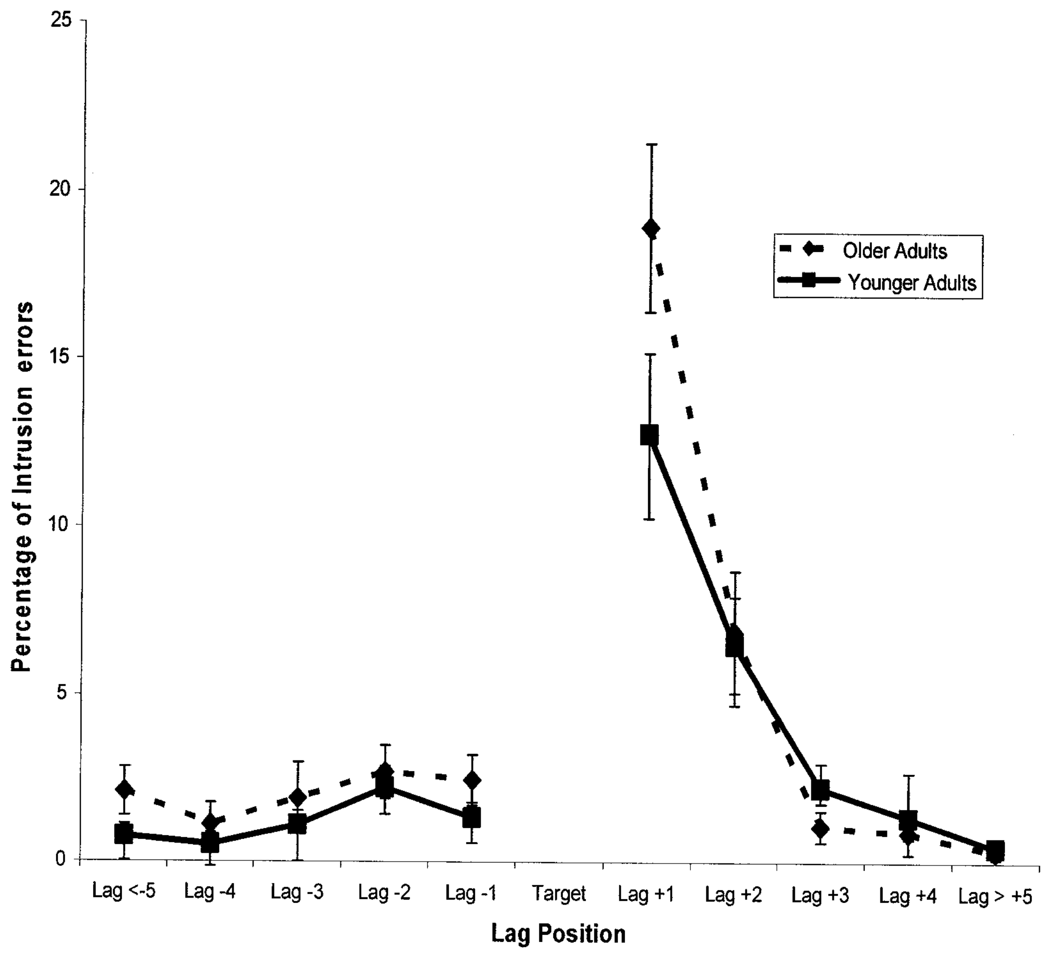


Figure 3.

*Intrusion Error Rates by Age and Lag Position for "smoking a cigarette"*

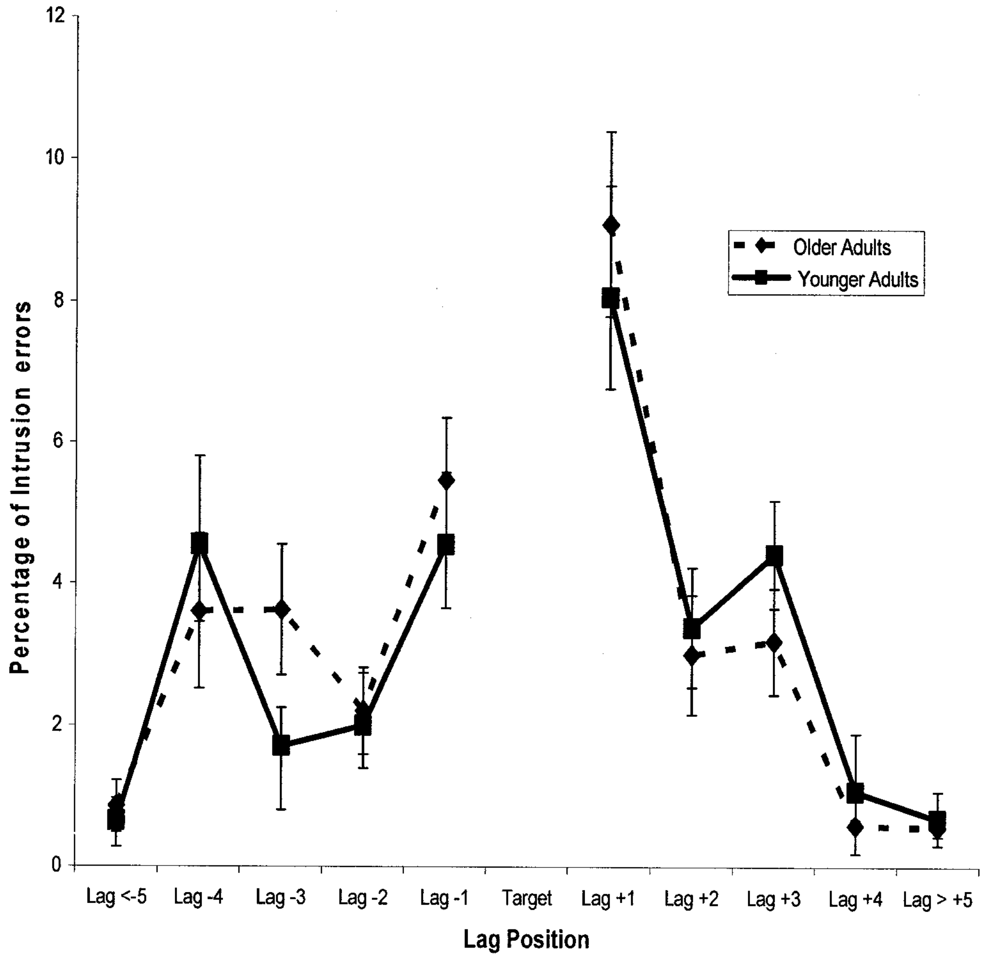
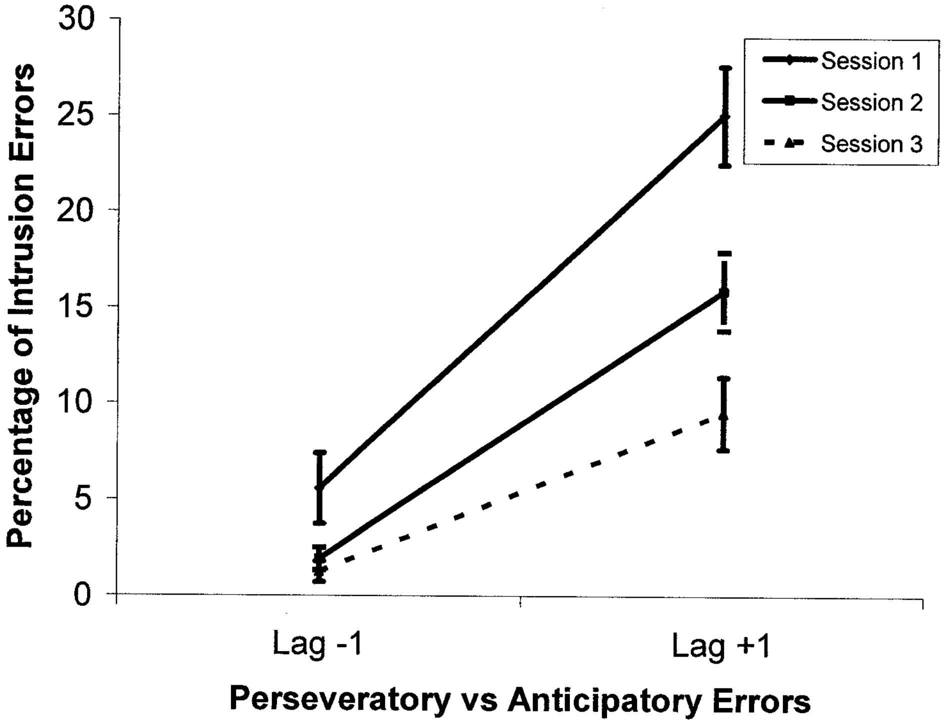


Figure 4a.

*Intrusion Error Rates in Older Adults for "writing and posting a letter" by Session*



Figures 4b.

*Intrusion Error Rates in Younger Adults for "writing and posting a letter" by Session*

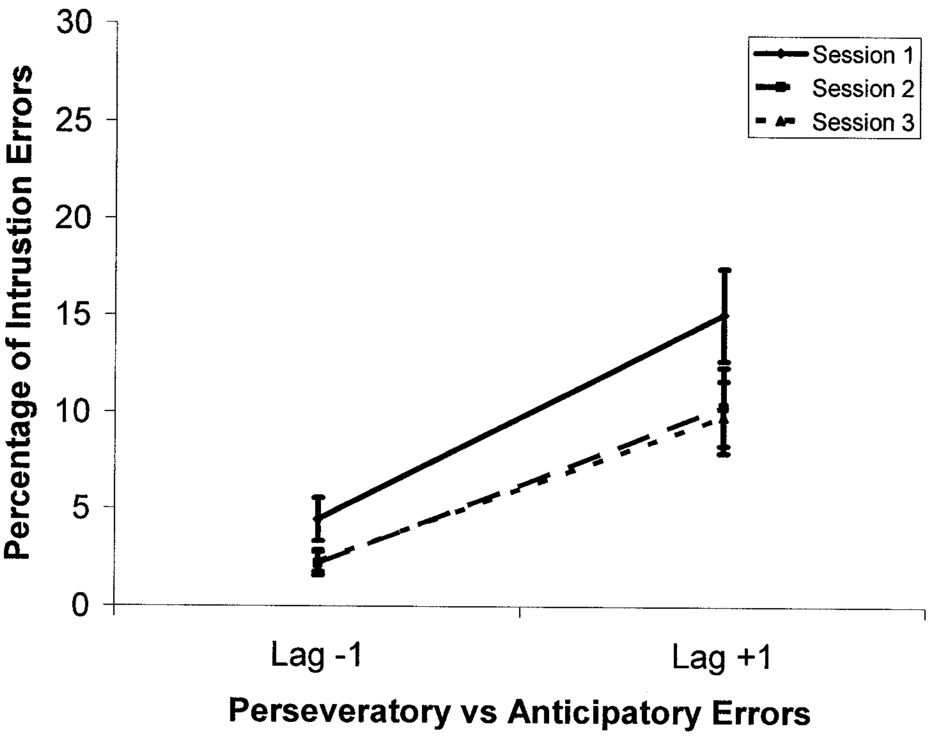


Figure 5a.

*Intrusion Error Rates for "wrapping a gift" by Age Group*

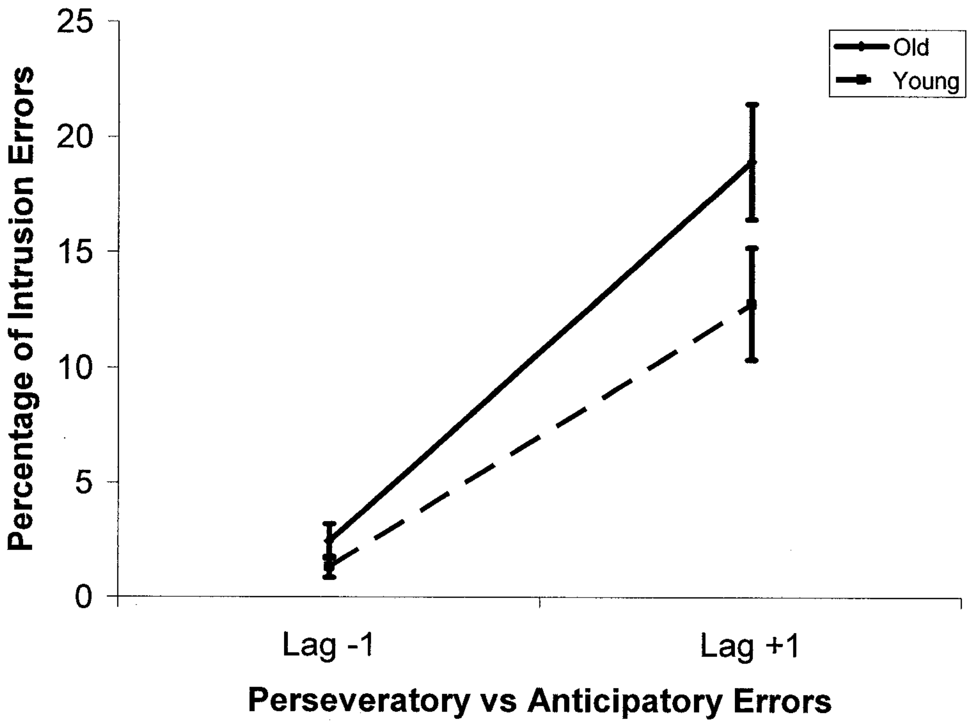
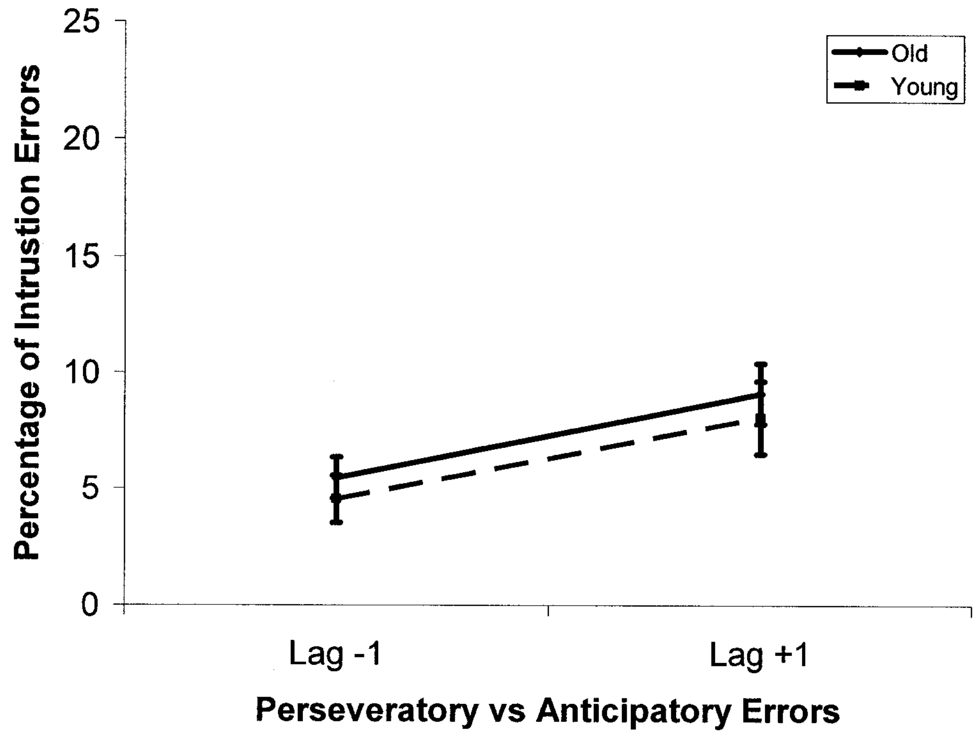


Figure 5b.

*Intrusion Error Rates for "smoking a cigarette" by Age Group*



## References

Allaire, J.C., & Marsiske, M. (2005). Intraindividual variability may not always indicate vulnerability in elders' cognitive performance. *Psychology and Aging, 20*, 390 – 401.

Anstey, K. J. (1999). Sensorimotor and forced expiratory volume as correlates of speed, accuracy, and variability in reaction time performance in late adulthood. *Aging, Neuropsychology, and Cognition, 6*, 84-95.

Arbuthnott, K. D. (1996). To repeat or not to repeat: Repetition facilitation and inhibition in sequential retrieval. *Journal of Experimental Psychology: General, 125*, 261-283.

Baddeley, A. (1986). *Working Memory.* Oxford: Clarendon Press.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49A*, 5-28.

Band, G.P.H., Ridderinkhof, K.R., & Segalowitz, S. (2002). Explaining neurocognitive aging: Is one factor enough? *Brain and Cognition, 49*, 259-267.

Bellgrove, M.A., Hester, R., & Garavan, H. (2004). The functional neuroanatomical correlates of response variability: Evidence from a response inhibition task. *Neuropsychologia, 42,* 1910-1916.

Bench, C.J., Frith, C.D., Graspy, P.M., Friston, K.J., Paulosu, E., Frackwiak, R.S. (1993). Investigations of the functional anatomy of attention using the stroop test. *Neuropsychologia, 31*, 907-922.

Bleiberg, J., Garmoe, W. S., Halpern, E. L., Reeves, D. L., & Nadler, J. D. (1997). Consistency of within-day and across-day performance after mild brain injury.

*Neuropsychiatry, Neuropsychology, and Behavioural Neurology, 10*, 247-253.

Bryan. J. & Luszcz M.A. (2000). Measurement of executive function: Consideration for detecting adult age differences. *Journal of Clinical and Experimental Neuropsychology, 22*, 40-55.

Burgess, P. (1998). Theory and methodology in executive function research. In: P. M. A. Rabbitt (Ed.), *Methodology of frontal and executive function* (pp. 81-116). Hove, England: Psychology Press.

Cepeda, N. J., Kramer, A.F., & Gonzalez de Sather, J.C.M. (2001). Changes in executive control across the life span : Examination of task-switching performance. *Developmental Psychology, 37*, 715-730.

Chow, V. (2002). *The role of inhibition and natural order on sequential action. regulation.* Unpublished honour's thesis, Concordia University, Montreal, Quebec, Canada.

Christensen, H., Mackinnon, A.J., Korten, A.E., Jorm, A.F., Henderson, A. S., & Jacomb, P. (1999). Dispersion in cognitive ability as a function of age: A longitudinal study of an elderly community sample. *Aging, Neuropsychology, and Cognition, 6*, 214-228.

Christensen, H., Mackinnon, A. J., Korten, A., Jorm, A. F. (2001). The "Common Cause Hypothesis" of cognitive aging: Evidence for not only a common factor but also specific associations of age with vision and grip strength in a cross sectional analysis. *Psychology and Aging, 16*, 588-599.

Cooper, R. & Shallice, T. (2000). Contention scheduling and the control of routine Activities. *Cognitive Neuropsychology, 17*, 297-338.

Crawford, J.R., Bryan, J., Luszcz, M. A., Obonsawin, M. C., & Stewart, L. (2000). The executive decline hypothesis of cognitive aging: Do executive deficits qualify as differential deficits and do they mediate age-related memory decline? *Aging, Neuropsychology, and Cognition, 7*, 9-31.

Dell, G.S., Burger, L.K. & Svec, W.R. (1997). Language production and serial order: A Functional analysis and a model. *Psychological Review, 104*, 123-147.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*, 45-75.

Dupuis, K., Li, K. Z. H., & Ward, M. (2005, July). *Investigating age differences in inhibitory abilities and sequential action regulation.* Poster presented at the Joint meeting of the Canadian Society for Brain, Behaviour, and Cognitive Science and the Experimental Psychology Society, Montreal, Canada.

Engle, R.W., Conway, A.R.A., Tuholski, S.W., & Shisler, R.J. (1995). A resource account of inhibition. *Psychological Science, 6*, 122-125.

Eslinger, P.J. (1996). Conceptualizing, describing, and measuring components of executive function: A summary. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory and executive function* (pp. 367-395). Baltimore, MD: Paul H. Brookes.

Estes, W. K. (1972). An associative basis for coding and organization in memory. In A. W. Melton & E. Martin (Eds.), *Coding processes in human memory* (pp.161-190). Washington, DC: Winston.

Fisk, J., & Warr, P. (1996). Age and working memory: The role of perceptual speed, the central executive, and the phonological loop. *Psychology and Aging, 11*, 316-323.

Grafman, J. (1995). Similarities and distinctions among current models of prefrontal cortical functions. *Annals of the New York Academy of Sciences, 769*, 337-368.

Greenwood, P. M. The frontal aging hypothesis evaluated. *Journal of the International Neuropsychological Society, 6*, 705-726.

Fuentes, K., Hunter, M. A., Strauss, E., & Hultsch, D. F. (2001). Intraindividual variability in cognitive performance in persons with chronic fatigue syndrome. *Clinical Neuropsychologist, 15*, 210-227.

Hasher, L., Stoltzfus, E. R., Zacks, R. T., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory and Cognition, 17*, 163-169.

Hasher, L., & Zacks, R.T. (1988). Working memory, comprehension, and aging: A review and a new view. In G.H. Bower (Ed.), *The psychology of learning and motivation* (Vol.22, pp. 193-225). New York: Academic.

Hasher, L., Zacks, R.T. & May, C.P. (1999). Working memory, comprehension, and Aging: A review and a new view. In G.H. Bower (Ed.), *The psychology of learning and motivation*_(Vol.22, pp. 193-225). New York: Academic Press.

Hertzog, C., & Schaie, K. W. (1986). Stability and change in adult intelligence: I. Analysis of longitudinal covariance structures. *Psychology and Aging, 1*, 159-171.

Houghton, G. (1990). The problem of serial order: A neural network model of sequence learning and recall. In R. Dale, C. Mellish, & M. Zock (Eds.), *Current research in natural language generation*. London: Academic Press.

Houghton, G., Glasspool, D. W., & Shallice, T. (1994) Spelling and serial recall: Insights

From a competitive queueing model. In G. D. A. Brown & N. C. Ellis (Eds.), *Handbook of Spelling: Theory, Process, and Intervention.* New York: John Wiley & Sons Ltd.

Houghton, G., & Tipper, S.P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. Carr (Eds.), *Inhibitory mechanisms in attention memory and language.* San Diego, CA: Academic Press.

Houghton, G. & Tipper, S.P. (1996). Inhibitory mechanisms of neural and cognitive control: Applications to selective attention and sequential action. *Brain and Cognition, 30*, 20-43.

Houx, P., Jolles, J., & Vreeling, F. (1993). Stroop interference : Aging effects assessed with Stroop color-word test. *Experimental Aging Research, 19*, 209-224.

Hultsch, D.F., & MacDonald, S.W.S. (2004). Intraindividual variability in performance as a theoretical window onto cognitive aging. In R.A. Dixon, L. Backman, & L.G. Nilsson (Eds.), *New frontiers in cognitive aging* (pp. 65-88). New York: Oxford University Press Inc.

Hultsch, D.F., MacDonald, S.W., Hunter, M., Levy-Bencheton, J., & Strauss, E. (2000). Intraindividual variability in cognitive performance in the elderly: Comparison of adults with mild dementia, adults with arthritis, and healthy adults. *Neuropsychology, 14*, 588-598.

Humphreys, G. W. & Forde, E. M. E. (1998). Disordered action schema and action disorganisation syndrome. *Cognitive Neuropsychology, 15*, 771-811.

Kramer, A.F., Humphrey, D.G., & Larish, J.F., Logan, G.D., Strayer, D.L. (1994). Aging and inhibition: Beyond a unitary view of inhibitory processing in attention.

*Psychology and Aging, 9*, 491-512.

Kramer, A.F., Martin-Emerson, R., Larish, J.F., & Anderson, G.J. (1996). Aging and filtering by movement in visual search. *Journal of Gerontology: Psychological Sciences, 51B*, P201-P216.

Kramer, A.F., Hahn, S., & Gopher, D. (1999). Task coordination and aging: Explorations Executive control processes in the task switching paradigm. *Acta Psychologia, 101*, 339-378.

Lashley, K. S. (1951). The problem of serial order in behaviour. In L. A. Jeffress (Ed.), *Cerebral mechanisms in behaviour* (pp. 112-136). New York: Wiley.

Levinoff, E.J., Li, K.Z.H, Murtha, S. & Chertkow, H. (2004). Selective attention impairments in Alzheimer's disease: Evidence for dissociable components. *Neuropsychology, 18*, 580-588.

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). London: Oxford University Press.

Li, K. Z. H., Lindenberger, U., Rünger, D., & Frensch, P. A. (2000). The role of inhibition in the regulation of sequential action. *Psychological Science*, 11, 343-347.

Li, S.-C., Aggen, S. H., Nesselroade, J. R., & Baltes, P. B. (2001). Short-term fluctuations in elderly people's sensorimotor functioning predict test and spatial memory performance: The MacArthur Successful Aging Studies. *Gerontology, 47*, 100-116.

Li, S.-C., & Lindenberger, U. (1999). Cross-level unification: A computational exploration of the link between deterioration of neurotransmitter systems and dedifferentiation of cognitive abilities in old age, In L-G. Nilsson & H. Markowitsch (Eds.), *Cognitive neuroscience and memory* (pp. 103-146). Toronto, Ontario, Canada: Hogrefe & Huber.

Logan, G. D. (2004). Working memory, task switching, and executive control in the task span procedure. *Journal of Experimental Psychology: General, 133*, 218-136.

Lowe, C., & Rabbitt, P. (1998). Test/re-test reliability of the CANTAB and ISPOCD Neuropsychological batteries: theoretical and practical issues. *Neuropsychologia, 36*, 915-923.

MacLeod, C. M. (1991). Half a century of research on the stroop effect: An integrative Review. *Psychological Bulletin, 109*, 163-203.

Maylor, E. A., & Hensen, R. N. A. (2000). Aging and the Ranschburg effect: No evidence of reduced response suppression in old age. *Psychology and Aging, 15*, 657-670.

Maylor, E. A., Schlaghecken, F., & Watson, D. G. (2005). Aging and inhibitory processes in memory, attentional and motor tasks. In R.W. Engle, G. Sedek, U Von Hecker, & D. N. McIntosh (Eds.), *Cognitive limitations in aging and psychopathology*, Cambridge: Cambridge University Press.

McDowd, J.M., Oseas-Kreger, D.M., & Filion, D.L. (1995). Inhibitory processes in cognition and aging. In F.N. Dempster & C.J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp.363-400). San Diego: Academic Press.

McDowd, J.M. & Fillion, D.L. (1992). Aging, selective attention, and inhibitory Processes: A psychophysiological approach. *Psychology and Aging, 7*, 65-71.

Miller, G.A., Galanter, E., Pribram, K.H. (1960). *Plans and the structure of behavior.*

New York: Holt, Rinehart, & Winston.

Milner, B. (1971). Interhemispheric differences in the localization of psychological processes in man. *British Medical Bulletin, 27*, 272-277.

Miyake, A., Friedman, N.P., Rettinger, D.A., Shah, P., & Hegarty, M. (2001). How are Visuospatial working memory, executive functioning, and spatial abilities related? A latent-variable analysis. *Journal of Experimental Psychology: General, 130,* 621-640.

Miyake, A., Friedman, N.P., Emerson, M.J., Witzki, A.H., Howerter, A., & Wager, T.D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100.

Moscovitch, M., & Winocur, G. (1995). Frontal lobes, memory, and aging. *Annals of the New York Academy of Sciences, 769*, 119-150.

Moscovitch, M., & Winocur, G. (1992). The neuropsychology of memory and aging. In F.I.M. Craik and T.A. Salthouse (Eds.), *The handbook of aging and cognition* (pp. 315-371). Hillsdale, NJ: Erlbaum.

Murtha, S., Cismaru, R., Waechter, R., & Chertkow, H. (2002). Increased variability accompanies frontal lobe damage in dementia. *Journal of the International Neuropsychological Society, 8*, 360-372.

Nesselroade, J. R. (1991). The warp and woof of the developmental fabric. In R. M. Downs & L. S. Liben (eds.), *Visions of aesthetics, the environment, & development: The legacy of Joachim F. Wohlwill.* (pp. 213-240). New Jersey, England: Lawrence Erlbaum Associates.

Norman, D.A., & Shallice, T. (1986). Attention to action: Willed and automatic control of behaviour. In R.J. Davidson, G.E. Schwartz & D. Shapiro (Eds.), *Consciousness and self regulation*. New York: Plenum Press.

Psychological Corporation. (1997a). WAIS-III Technical Manual. San Antonio, TX: Psychological Corporation.

Psychological Corporation. (1997b). WMS-III Technical Manual. San Antonio, TX: Psychological Corporation.

Rabbitt, P. (1965). An age decrement in the ability to ignore irrelevant information. *Journal of Gerontology, 20*, 233-237.

Rabbit, P. (2003). Aging and Cognition. In H. Pashler & J. Wixted (Eds.), *Stevens' Handbook of experimental psychology, 3rd Edition, Volume 4: Method* (pp. 793-860). New York: Wiley.

Rabbitt, P. & Lowe, C. (2000). Patterns of cognitive ageing. *Psychological Research, 63*, 308-316.

Reason, J. (1984). Lapses of attention in everyday life. In R. Parasuraman & D. R. Davies (Eds.), *Varieties of attention* (pp. 515-549). Orlando, FL: Academic Press.

Robbins, T. W., James, J., Owen, A. M., Sahakian, B. J., Lawrence, A. D., Mcinnes, L., & Rabbitt, P. M. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: Implications for theories of executive functioning and cognitive aging. *Journal of the International Neuropsychological Society, 4*, 474-490.

Rogers, W., & Fisk, A.D. (1991). Age-related differences in the maintenance and modification of automatic processes: Arithmetic Stroop interference. *Human*

*Factors, 33*, 45-56.

Rünger, D. (2002). *The regulation of sequential action: S-ACT revisited.* Unpublished Master's thesis, Humboldt-Universität zu Berlin.

Sattler, J. M., & Ryan, J. J. (1999). *Assessment of children: Revised and Updated Third Edition WAIS-III Supplement.* San Diego: Jerome M. Sattler.

Salthouse, T. A. (1993). Attentional blocks are not responsible for age-related slowing. *Journal of Gerontology: Psychological Sciences, 48*, P263-P270.

Salthouse, T. A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review, 103 (3),* 403-428.

Salthouse, T. A., Atkinson, M., & Berish, D. E. (2003). Executive functioning as a potential mediatory of age-related cognitive decline in normal adults. *Journal of Experimental Psychology, 132*, 566-594.

Salthouse, T. A. (2004). What and when of cognitive aging. *Current Directions in Psychological Science, 13,* 140-144.

Schaie, K. W. (1996). *Intellectual development in adulthood: The Seattle Longitudinal Study*. Cambridge, UK: Cambridge University Press.

Schwartz, M.F., & Buxbaum, L.J. (1997). Naturalistic action. In L.J.G. Gonzalez & K.M. Heilman (Eds.), *Apraxia: The neuropsychology of action* (pp. 269-289). Hove, England: Psychology Press/Erlbaum (UK) Taylor & Francis.

Schwartz, M. F., Mayer, N. H., Fitzpatrick-DeSalme, E.J., & Montgomery, M.W. (1993). Cognitive theory and the study of everyday action disorders after brain damage. *Journal of Head Trauma and Rehabilitation, 8,* 59-72.

Schwartz, M. F., Montgomery, M.W., Fitzpatrick-DeSalme, E.J.,Ochipa, C., Coslett, H.B., & Mayer, N.H. (1995). Analysis of a disorder of everyday action. Cognitive *Neuropsychology, 12*, 863-892.

Scialfa, C. T., & Joffe, K. M. (1997). Age differences in feature and conjunction search: Implications for theories of visual search and generalized slowing. *Aging, Neuropsychology, & Cognition, 4,* 227-246.

Segalowitz, N., Poulsen, C., & Segalowitz, S. (1998). RT coefficient of variation is differentially sensitive to executive control involvement in an attention switching task. *Brain and Cognition, 40*, 255-258.

Segalowitz, N., & Segalowitz, S. (1993). Skilled performance, practice, and the differentiation of speed-up from automatization effects: Evidence from second language word recognition. *Applied Psycholinguistics, 14*, 369-385.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662.

Stuss, D. T., & Alexander, M.P. (2000). Executive functions and the frontal lobes: A conceptual view. *Psychological Research, 63*, 289-298.

Stuss, D.T., Murphy, K.J., Binns, M.A., & Alexander, M.P. (2003). Staying on the job: The frontal lobes control individual performance variability. *Brain, 126*, 2363-2380.

Stuss, D.T., Stethem, L.L., Hugenholtz, H., Picton, T., Pivik, J., & Riachar, M.T. (1989). Reaction time after head injury: Fatigue, divided and focused attention, and consistency of performance. *Journal of Neurology, Neurosurgery and Psychiatry, 52*, 742-748.

Stuss, D.T., Pogue, J., Buckle, L., & Bonder, J. (1994). Characterization of variability of performance in patients with traumatic brain injury: Variability and consistency on reaction time tests. *Neuropsychology, 8*, 316-324.

Stuss, D.T., Murphy, K.J., & Binns, M.A. (1999). The frontal lobes and performance variability: Evidence from reaction time. *Journal of the International Neuropsychological Society, 5,* 123.

Troyer, A.K., Graves, R.E., & Cullum, C.M. (1994). Executive functioning as a mediator of the relationship between age and episodic memory in healthy aging. *Aging and Cognition, 1*, 45-53.

Van der Linden, M., Beerten, A., & Pesenti, M. (1998). Age-related differences in random generation. *Brain and Cognition, 38*, 1-16.

Wecker, N. S., Kramer, J. H., Wisniewski, A., Delis, D. C., & Kaplan, E. (2000). Age effects on executive ability. *Neuropsychology, 14*, 409-414.

West, R.L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120*, 272-292.

Williams, B.R., Hultsch, D.F., Strauss, E.H., Hunter, M.A., & Tannock, R. (2005). inconsistency in reaction time across the life span. *Neuropsychology, 19*, 88-96.

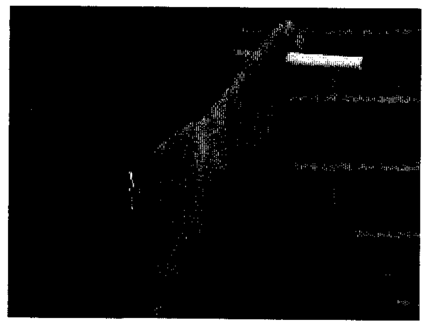
Zacks, R., & Hasher, L. (1997). Cognitive gerontology and attentional inhibition: A reply to Burke and McDowd. *Journal of Gerontology: Psychological Sciences, 52B*, P274-P283.

Appendix A

*Pictorial Representations of Steps to Complete Everyday Tasks*

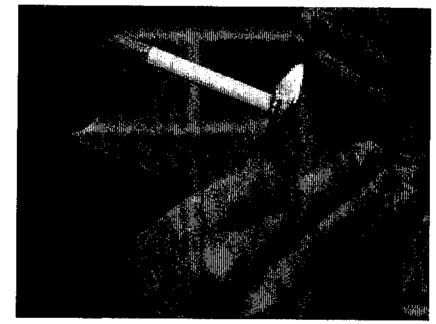
Smoking a Cigarette

**Get cigarette out of pack**

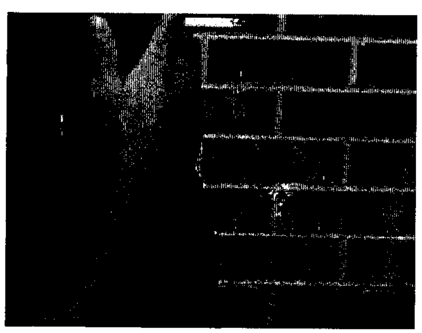


**Put cigarette in mouth**

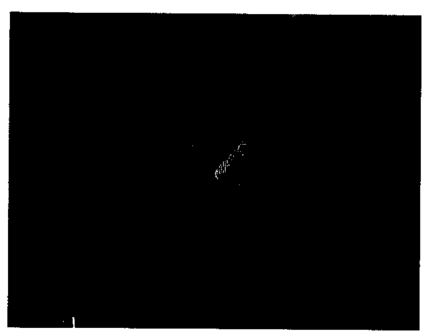
**Strike match**



**Light the cigarette**



**Inhale**

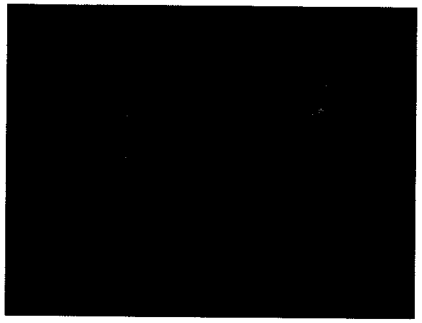


**Exhale**

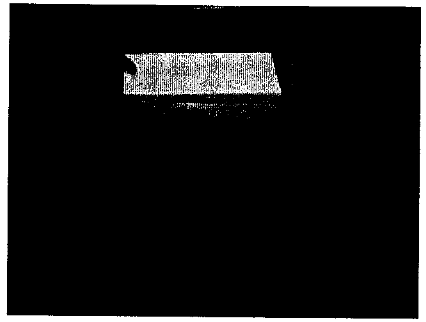
**Flick ash in ashtray**

**Stub out the cigarette**

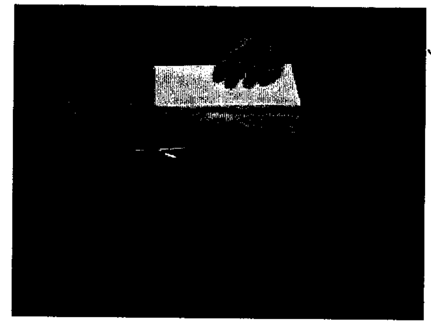
Wrapping a Gift



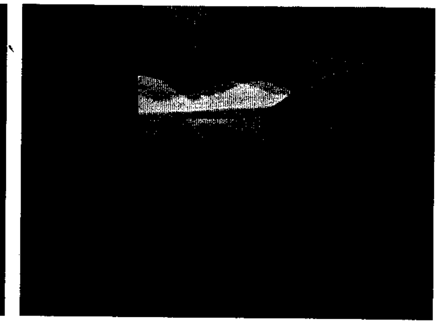
**Unfold the paper**



**Put gift in center**



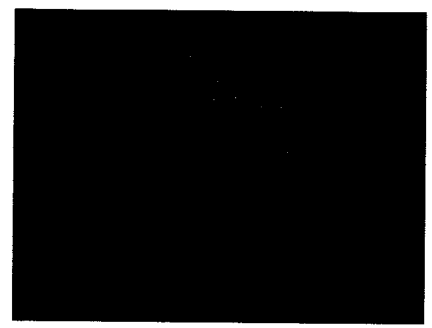
**Cut the paper**



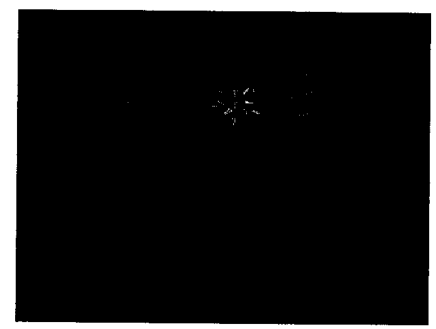
**Fold the paper over gift**

**Secure the selotape**

**Fix one end**



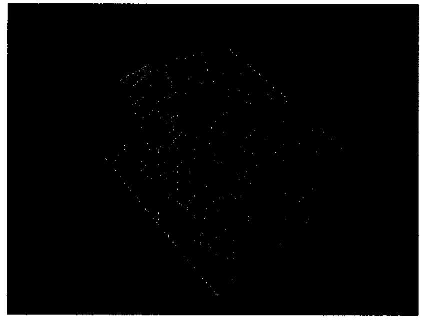
**Fix the other end**



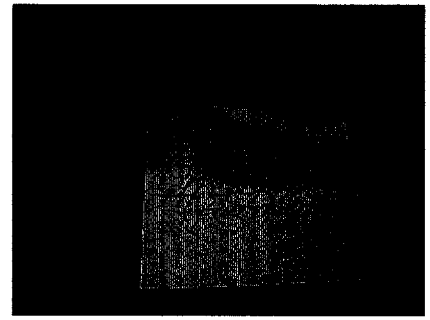
**Stick bow on top**

Writing and Posting a Letter

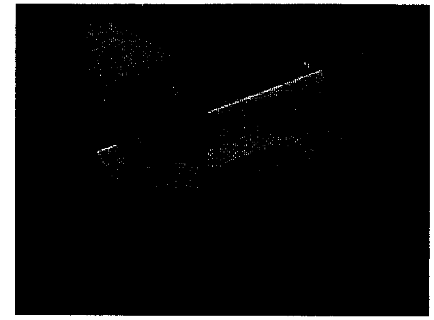
Write the letter



Sign the letter

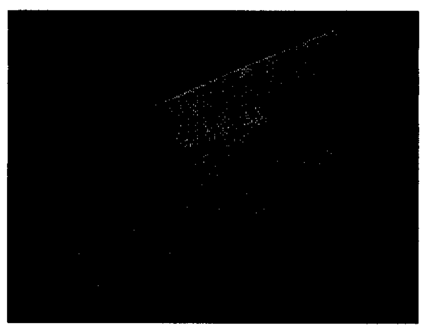


Fold the letter

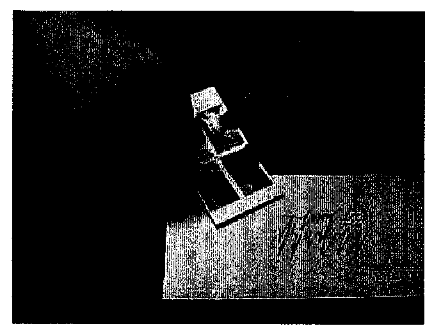


Put letter in envelope

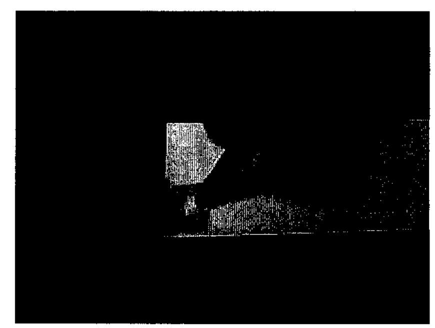
Seal by pressing down



Write address on envelope



Take stamp



Stick stamp on envelope

Appendix B

*Computerized Instructions for the SA Paradigm*[a]

# Welcome!
# In this computer program, you will be asked to 'complete' an everyday task.

# Your task is:

# "Wrapping a gift"

[a] For the purposes of this paper, the instructions to "wrapping a gift" are displayed. Instructions for all three tasks did not vary from one another.

**In order to complete the tasks, you will first memorize the steps to each task. Afterwards, you will press the "yes" key every time you see the correct step in the sequence of the task until you have completed all 8 steps.**

**The steps are in scrambled order and will appear one at a time, briefly at a fixed pace. Your job is to monitor for the step that follows in the correct order to complete the task.**

**Press the "yes" key only when you see the next step that is necessary to complete the task.**

**You will be viewing several pictures of steps required to complete the task of 'wrapping a gift'.**

- **Unfold the paper**
- **Put gift in center**
- **Cut the paper**
- **Fold the paper over the gift**
- **Secure the tape**
- **Fix one end**
- **Fix the other end**
- **Stick bow on top**

**Notice that the steps are arranged in the correct order to successfully complete the task.**

**The pictures that you will be viewing will be in scrambled order. They will appear one at a time, briefly at a fixed pace. Your job is to monitor for the steps to complete the task in the order that you have learned.**

**Press the "yes" key only when you see the next step in the task.**

**For example, you should first monitor for the picture that represents, “unfold the paper“. Once you see that picture appear, you would press the “yes” key.**

**However, if a picture representing another step such as, “fix one end” appears, you would not respond. Then, you will monitor for the picture that represents the second step in the sequence, “put gift in center“. Respond only when you see the picture that you are looking for. If you are unsure about the order of the steps necessary to complete the task, please feel free to consult the picture key next to the computer in between trials.**

*Counterbalancing of Blocks 1-3*

*Block 1*

| Sequence # | Sequence Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | lag +7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17 | | 1 | 2 | 6 | 3 | 3 | 4 | 5 | 6 | | | 5 | 7 | | 4 | | 8 | |
| 2 | 15 | 5 | | 1 | 6 | 2 | 3 | 2 | | 4 | 2 | 5 | 6 | | 7 | 8 | | | |
| 3 | 16 | 1 | 5 | | | 2 | 2 | 6 | 3 | | 4 | | 5 | | 6 | 7 | 8 | | |
| 4 | 17 | | 5 | | 1 | 6 | 2 | 3 | 7 | 1 | 4 | 4 | 8 | 5 | 6 | 7 | 5 | 8 | lag +3 |
| 5 | 17 | | 1 | 2 | | 6 | 3 | 4 | 1 | 5 | 3 | 6 | 4 | | 7 | 7 | 5 | 8 | |
| 6 | 16 | | 5 | 1 | | 2 | 2 | | 3 | 4 | | 8 | 5 | 6 | | 7 | 8 | | |
| 7 | 16 | 1 | 6 | 5 | 2 | 7 | 2 | 3 | 4 | 4 | | 8 | 5 | | 6 | 7 | 8 | | lag -1 |
| 8 | 17 | 4 | 1 | 1 | 2 | 3 | 2 | 4 | | 5 | 6 | 6 | 3 | | 7 | | 5 | 8 | |
| 9 | 15 | | | 1 | 2 | 1 | 3 | 3 | 4 | | 5 | | 6 | 7 | 4 | 8 | | | lag -3 |
| 10 | 15 | 1 | 2 | 6 | 3 | 3 | | 4 | 5 | | 6 | | | 7 | 7 | 8 | | | lag -4 |
| 11 | 16 | 1 | 2 | 2 | 3 | 4 | | 5 | | 6 | | | 7 | 4 | | 5 | 8 | | |
| 12 | 15 | 1 | | 2 | 3 | 7 | 4 | 4 | | 5 | 5 | 6 | | | 7 | 8 | | | |
| 13 | 16 | | 1 | | | 5 | 2 | 2 | 3 | 1 | 4 | 3 | 5 | 6 | 4 | 7 | 8 | | lag -7 |
| 14 | 15 | | 1 | 2 | | | 3 | 1 | 4 | 3 | 5 | 6 | 5 | 7 | 7 | 8 | | | |
| 15 | 17 | 4 | | 1 | 6 | | 1 | 2 | 3 | | 4 | 8 | 5 | 6 | 3 | 7 | | 8 | |
| 16 | 15 | 1 | 1 | | 2 | 3 | 7 | 8 | 4 | 2 | 5 | 6 | 3 | | 7 | 8 | | | |
| 17 | 17 | 1 | 2 | | 1 | | 3 | 1 | 4 | 5 | 4 | 6 | | 7 | 5 | | | 8 | |
| 18 | 15 | 5 | 1 | 2 | | 3 | 4 | | 3 | 8 | 5 | 6 | | | 7 | 8 | | | |
| 19 | 15 | 8 | 1 | | 2 | 7 | 3 | 2 | | 4 | 3 | 5 | 6 | 6 | 7 | 8 | | | |
| 20 | 17 | 1 | 2 | 2 | 1 | 3 | | 4 | 5 | 3 | | | 6 | 7 | 5 | | 1 | 8 | |
| 21 | 17 | 1 | 2 | | 3 | 2 | 4 | 8 | 5 | | | 3 | 6 | 6 | 7 | 5 | 4 | 8 | |
| 22 | 17 | | 5 | 1 | 2 | 2 | | 3 | 4 | | 5 | | 1 | | 6 | 6 | 7 | 8 | |
| 23 | 16 | 1 | | | | 2 | | 3 | | 4 | 5 | 4 | 6 | 7 | | 1 | 8 | | |
| 24 | 17 | | 1 | 2 | | 3 | 2 | 4 | | | 5 | | 6 | | 7 | | 4 | 8 | |
| 25 | 16 | | 1 | 2 | | | | 3 | 4 | | 8 | 5 | 3 | 6 | | 7 | 8 | | |
| 26 | 15 | 1 | 2 | 3 | | 7 | 4 | | | 5 | | 6 | | 3 | 7 | 8 | | | |
| 27 | 17 | 4 | 1 | | | 5 | 2 | | | 3 | | 4 | 1 | 5 | 6 | 7 | 7 | 8 | |
| 28 | 15 | 8 | 1 | 2 | | 1 | | 3 | | 4 | 5 | 2 | 6 | 7 | 4 | 8 | | | |
| 29 | 16 | | | 1 | | 2 | 3 | | 4 | 1 | 5 | 2 | 4 | 6 | 7 | 5 | 8 | | |
| 30 | 15 | 1 | | 2 | | 7 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 1 | 7 | 8 | | | |
| 31 | 16 | 1 | | | | 2 | 1 | 3 | | 7 | 4 | 5 | 5 | 6 | | 7 | 8 | | |
| 32 | 15 | 1 | 2 | 2 | 3 | | 4 | | 5 | 3 | 5 | 6 | 4 | 7 | 1 | 8 | | | |
| 33 | 16 | | 1 | | 2 | 3 | 7 | 4 | | 1 | 8 | 5 | 2 | 6 | 7 | 5 | 8 | | |
| 34 | 16 | 8 | 1 | 2 | 1 | 3 | 3 | 4 | | 5 | 5 | | 6 | | 4 | 7 | 8 | | |
| 35 | 17 | | | 1 | 1 | 2 | 2 | | 3 | | 4 | | 5 | | 6 | 3 | 7 | 8 | |
| 36 | 15 | 1 | 1 | 2 | 3 | | 4 | 5 | | 6 | | 7 | 5 | 7 | | 8 | | | |
| 37 | 15 | | 1 | | 2 | 3 | 1 | 4 | 2 | | 5 | | 6 | | 7 | 4 | 8 | | |
| 38 | 16 | 1 | 2 | | 3 | 4 | 4 | | 5 | 2 | | 6 | 3 | 7 | 7 | 1 | 8 | | |
| 39 | 16 | | 1 | | 2 | | 2 | 3 | 7 | 4 | 5 | | 6 | | 7 | | 8 | | |
| 40 | 16 | | 1 | | 2 | 1 | | 3 | 7 | 2 | 4 | 3 | 5 | 6 | | 7 | 5 | 8 | |
| 41 | 17 | 1 | | 2 | 7 | 1 | | 3 | 8 | 4 | 2 | 3 | 5 | 6 | | 7 | | 8 | |
| 42 | 17 | 1 | | 2 | 1 | 3 | 4 | 2 | 8 | 5 | 3 | 6 | | 7 | | | 7 | 8 | |

*Block 2*[b]

| Sequence # | Sequence Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | lag +7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | 16 | 1 | 6 | 5 | 2 | 7 | 2 | 3 | 4 | 4 | | 8 | 5 | | 6 | 7 | 8 | | |
| 6 | 16 | | 5 | 1 | | 2 | 2 | 4 | 3 | 4 | 3 | 8 | 5 | 6 | | 7 | 8 | | |
| 14 | 15 | | 1 | 2 | | 4 | 3 | 1 | 4 | 3 | 5 | 6 | 5 | 7 | 7 | 8 | | | |
| 10 | 15 | 1 | 2 | 6 | 3 | 3 | 8 | 4 | 5 | | 6 | | 5 | 7 | 7 | 8 | | | lag +3 |
| 11 | 16 | 1 | 2 | 2 | 3 | 4 | 6 | 5 | | 6 | | | 7 | 4 | | 5 | 8 | | |
| 5 | 17 | | 1 | 2 | | 6 | 3 | 4 | 1 | 5 | 3 | 6 | 4 | | 7 | 7 | 5 | 8 | |
| 12 | 15 | 1 | | 2 | 3 | 7 | 4 | 4 | 6 | 5 | 5 | 6 | | | 7 | 8 | | | lag -1 |
| 30 | 15 | 1 | | 2 | | 7 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 1 | 7 | 8 | | | |
| 41 | 17 | 1 | | 2 | 7 | 1 | | 3 | 8 | 4 | 2 | 3 | 5 | 6 | 5 | 7 | 6 | 8 | lag -3 |
| 8 | 17 | 4 | 1 | 1 | 2 | 3 | 2 | 4 | | 5 | 6 | 6 | 3 | | 7 | | 5 | 8 | lag -4 |
| 39 | 16 | | 1 | | 2 | | 2 | 3 | 7 | 4 | 5 | 4 | 6 | | 7 | | 8 | | |
| 29 | 16 | | | 1 | 6 | 2 | 3 | 8 | 4 | 1 | 5 | 2 | 4 | 6 | 7 | 5 | 8 | | |
| 38 | 16 | 1 | 2 | | 3 | 4 | 4 | | 5 | 2 | | 6 | 3 | 7 | 7 | 1 | 8 | | lag -7 |
| 18 | 15 | 6 | 1 | 2 | | 3 | 4 | | 3 | 8 | 5 | 6 | | | 7 | 8 | | | |
| 19 | 15 | 8 | 1 | | 2 | 7 | 3 | 2 | | 4 | 3 | 5 | 6 | 6 | 7 | 8 | | | |
| 1 | 17 | | 1 | 2 | 6 | 3 | 3 | 4 | 5 | 6 | | | 5 | 7 | | 4 | | 8 | |
| 34 | 16 | 8 | 1 | 2 | 1 | 3 | 3 | 4 | | 5 | 5 | | 6 | | 4 | 7 | 8 | | |
| 32 | 15 | 1 | 2 | 2 | 3 | | 4 | | 5 | 3 | 5 | 6 | 4 | 7 | 1 | 8 | | | |
| 15 | 17 | 4 | | 1 | 6 | | 1 | 2 | 3 | | 4 | 8 | 5 | 6 | 3 | 7 | | 8 | |
| 9 | 15 | | | 1 | 2 | 1 | 3 | 3 | 4 | | 5 | | 6 | 7 | 4 | 8 | | | |
| 4 | 17 | | | | 1 | 6 | 2 | 3 | 7 | 1 | 4 | 4 | 8 | 5 | 6 | 7 | 5 | 8 | |
| 42 | 17 | 1 | | 2 | 1 | 3 | 4 | 2 | 8 | 5 | 3 | 6 | 5 | 7 | | | 7 | 8 | |
| 23 | 16 | 1 | | | | 2 | | 3 | | 4 | 5 | 4 | 6 | 7 | | 1 | 8 | | |
| 24 | 17 | 6 | 1 | 2 | | 3 | 2 | 4 | | | 5 | | 6 | | 7 | | 4 | 8 | |
| 31 | 16 | 1 | | | 5 | 2 | 1 | 3 | | 7 | 4 | 5 | 5 | 6 | | 7 | 8 | | |
| 27 | 17 | 4 | 1 | | 6 | 5 | 2 | | | 3 | | 4 | 1 | 5 | 6 | 7 | 7 | 8 | |
| 36 | 15 | 1 | 1 | 2 | 3 | | 4 | 5 | | 6 | | 7 | 5 | 7 | | 8 | | | |
| 20 | 17 | 1 | 2 | 2 | 1 | 3 | 8 | 4 | 5 | 3 | | | 6 | 7 | 5 | 6 | 1 | 8 | |
| 40 | 16 | | 1 | | 2 | 1 | | 3 | 7 | 2 | 4 | 3 | 5 | 6 | | 7 | 5 | 8 | |
| 25 | 16 | | 1 | 2 | | | | 3 | 4 | | 8 | 5 | 3 | 6 | | 7 | 8 | | |
| 3 | 16 | 1 | 5 | | | 2 | 2 | 6 | 3 | | 4 | | 5 | | 6 | 7 | 8 | | |
| 22 | 17 | | 5 | 1 | 2 | 2 | | 3 | 4 | | 5 | | 1 | | 6 | 6 | 7 | 8 | |
| 33 | 16 | | 1 | | 2 | 3 | 7 | 4 | | 1 | 8 | 5 | 2 | 6 | 7 | 5 | 8 | | |
| 21 | 17 | 1 | 2 | | 3 | 2 | 4 | 8 | 5 | | | 3 | 6 | 6 | 7 | 5 | 4 | 8 | |
| 28 | 15 | 8 | 1 | 2 | 7 | 1 | | 3 | | 4 | 5 | 2 | 6 | 7 | 4 | 8 | | | |
| 37 | 15 | | 1 | | 2 | 3 | 1 | 4 | 2 | | 5 | | 6 | | 7 | 4 | 8 | | |
| 13 | 16 | | 1 | | | 5 | 2 | 2 | 3 | 1 | 4 | 3 | 5 | 6 | 4 | 7 | 8 | | |
| 16 | 15 | 1 | 1 | | 2 | 3 | 7 | 8 | 4 | 2 | 5 | 6 | 3 | 5 | 7 | 8 | | | |
| 17 | 17 | 1 | 2 | | 1 | | 3 | 1 | 4 | 5 | 4 | 6 | | 7 | 5 | | 8 | 8 | |
| 35 | 17 | | | 1 | 1 | 2 | 2 | | 3 | | 4 | | 5 | 4 | 6 | 3 | 7 | 8 | |
| 2 | 15 | 5 | | 1 | 6 | 2 | 3 | 2 | | 4 | 2 | 5 | 6 | | 7 | 8 | | | |
| 26 | 15 | 1 | 2 | 3 | | 7 | 4 | | | 5 | | 6 | | 3 | 7 | 8 | | | |

[b] This block is the same as Block 1 except that the sequence numbers are presented in a different order.

*Block 3*

| Sequence # | Sequence Length | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 17 | 1 | 6 | | 2 | 3 | 2 | 1 | 4 | 1 | 3 | 4 | 5 | | 6 | 3 | 7 | 8 |
| 2 | 15 | | 1 | | 6 | 2 | | 1 | 3 | 4 | 3 | 5 | 6 | 4 | 7 | 8 | | |
| 3 | 16 | 1 | | 2 | | | 3 | 4 | 8 | 3 | 5 | 2 | 6 | 7 | 7 | | 8 | |
| 4 | 17 | 8 | | 1 | 2 | 2 | 3 | 6 | 2 | 4 | 5 | 3 | | 6 | 7 | 4 | 7 | 8 |
| 5 | 17 | 1 | 2 | 2 | | 3 | 3 | 4 | | 8 | 5 | 6 | 5 | 6 | | 7 | 7 | 8 |
| 6 | 16 | | | 1 | | 2 | 6 | 7 | 3 | 4 | 8 | 5 | 5 | 6 | 7 | 1 | 8 | |
| 7 | 16 | | 1 | 6 | | | 2 | 3 | 5 | 8 | 4 | 5 | 3 | 6 | | 7 | 8 | |
| 8 | 17 | | 5 | 1 | 2 | 1 | 6 | 3 | 4 | 2 | 4 | 5 | 6 | | 7 | | 5 | 8 |
| 9 | 15 | 4 | | | 1 | | 2 | 3 | | 1 | 4 | 5 | 6 | 3 | 7 | 8 | | |
| 10 | 15 | 5 | 1 | | | 2 | 3 | | 3 | 4 | 1 | 5 | 6 | | 7 | 8 | | |
| 11 | 16 | | 4 | 1 | 2 | 6 | 2 | 3 | 2 | 4 | 3 | 5 | | 6 | 7 | 1 | 8 | |
| 12 | 15 | | 1 | | 2 | 3 | | 8 | 4 | 5 | 6 | 4 | | 7 | 7 | 8 | | |
| 13 | 16 | | 5 | 1 | 1 | 2 | 3 | 7 | 2 | 4 | 4 | 5 | | 6 | 7 | | 8 | |
| 14 | 15 | 4 | 1 | 2 | | 2 | 6 | 3 | 4 | 3 | 5 | | 6 | 7 | 1 | 8 | | |
| 15 | 17 | | 1 | | 5 | 2 | 3 | | 1 | 4 | | 5 | 4 | 6 | 7 | 7 | | 8 |
| 16 | 15 | | 1 | 2 | 2 | 3 | 4 | 2 | 5 | 6 | 4 | 6 | 3 | 7 | 1 | 8 | | |
| 17 | 17 | | 1 | 1 | | 2 | | 3 | 4 | 4 | | 5 | | 6 | 7 | 6 | | 8 |
| 18 | 15 | 4 | | 1 | 2 | 2 | 3 | 3 | | 4 | 5 | | 6 | 7 | | 8 | | |
| 19 | 16 | | 1 | 1 | | 2 | 3 | | 4 | 8 | 5 | 6 | | 6 | 7 | 7 | 8 | |
| 20 | 17 | | 8 | 1 | 2 | 6 | 3 | 2 | 4 | 1 | 5 | 6 | 3 | 7 | 4 | 7 | 5 | 8 |
| 21 | 17 | | 1 | | 2 | 2 | 3 | 1 | 4 | 5 | 4 | 6 | 3 | | 7 | 5 | 6 | 8 |
| 22 | 17 | | 8 | 1 | | 2 | 1 | 3 | 7 | 4 | 4 | 5 | | 6 | 7 | 6 | 7 | 8 |
| 23 | 16 | 8 | | 1 | | 2 | 3 | 3 | 4 | 5 | 2 | 6 | 5 | 6 | | 7 | 8 | |
| 24 | 17 | | 1 | 2 | 6 | 3 | 4 | 3 | 5 | | 3 | | 6 | 4 | 7 | | 6 | 8 |
| 25 | 16 | | 5 | 1 | 2 | 6 | 3 | 4 | | 4 | 5 | | 3 | 6 | | 7 | 8 | |
| 26 | 15 | | 1 | 5 | 2 | | 1 | 3 | 1 | 4 | | 5 | 6 | 3 | 7 | 8 | | |
| 27 | 17 | 6 | | 1 | 2 | 2 | 3 | 1 | 4 | 5 | | 6 | | 3 | | 7 | 5 | 8 |
| 28 | 15 | | 1 | 2 | | 3 | 6 | 4 | 2 | 3 | 5 | | 6 | 7 | 5 | 8 | | |
| 29 | 16 | | 4 | 1 | 2 | 6 | 3 | | 2 | 4 | 3 | 5 | | 6 | 7 | 7 | 8 | |
| 30 | 15 | | 1 | 2 | | | | 3 | 4 | 3 | | 5 | 6 | | 7 | 8 | | |
| 31 | 16 | | 1 | 6 | 2 | 3 | 2 | 7 | 4 | 1 | 5 | 6 | 5 | | 4 | 7 | 8 | |
| 32 | 15 | 4 | 1 | 2 | | 3 | 7 | 4 | | 5 | | 6 | 3 | 6 | 7 | 8 | | |
| 33 | 16 | 4 | 1 | | 6 | 2 | 3 | 2 | 4 | 1 | | 5 | 5 | 6 | | 7 | 8 | |
| 34 | 16 | | 8 | 1 | 2 | 6 | 3 | | 1 | 4 | 3 | | 5 | 6 | 4 | 7 | 8 | |
| 35 | 17 | | 1 | 5 | 2 | | 3 | 3 | 4 | 5 | | | 6 | 4 | 6 | 7 | 6 | 8 |
| 36 | 15 | 8 | 1 | | 2 | 1 | 3 | | 4 | 5 | 4 | 6 | | 7 | 5 | 8 | | |
| 37 | 15 | | 1 | 2 | | | 3 | 7 | 4 | 4 | 3 | 5 | 6 | | 7 | 8 | | |
| 38 | 16 | | 1 | 5 | 2 | 6 | | 3 | 3 | 4 | 5 | 4 | | 6 | | 7 | 8 | |
| 39 | 15 | | 1 | 2 | | 3 | 1 | 4 | 8 | | 5 | 6 | 3 | 7 | 5 | 8 | | |
| 40 | 16 | 6 | 1 | 2 | 6 | 2 | | 3 | 3 | 4 | | 3 | 5 | 6 | | 7 | 8 | |
| 41 | 17 | | 1 | | 2 | | 3 | | 3 | 4 | 5 | | 6 | 5 | 7 | 7 | | 8 |
| 42 | 17 | | 4 | 1 | 6 | 2 | | 1 | 3 | 8 | 2 | 4 | 5 | | 6 | 6 | 7 | 8 |

lag +7

lag +3

lag -1

lag -3

lag -4

lag -7

Appendix D

*Summary of Number of Error Opportunities in Lag Bins in the Two Counterbalancing Orders*

Block 1 (and 2)

| Numbers | lag + 7 | lag +6 | lag +5 | lag + 4 | lag +3 | lag +2 | lag +1 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 |
| 3 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 10 |
| 4 | 0 | 0 | 0 | 0 | 3 | 7 | 9 | 19 |
| 5 | 0 | 0 | 0 | 6 | 4 | 5 | 5 | 20 |
| 6 | 0 | 0 | 5 | 7 | 4 | 5 | 11 | 32 |
| 7 | 0 | 6 | 7 | 8 | 8 | 8 | 4 | 41 |
| 8 | 3 | 2 | 8 | 5 | 9 | 8 | 7 | 42 |
| Total: | 3 | 8 | 20 | 26 | 28 | 37 | 46 | 168 |

| Numbers | lag -7 | lag -6 | lag -5 | lag -4 | lag -3 | lag -2 | lag -1 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 7 | 5 | 5 | 5 | 9 | 5 | 41 |
| 2 | 0 | 4 | 9 | 4 | 5 | 6 | 11 | 39 |
| 3 | 0 | 0 | 6 | 6 | 6 | 8 | 4 | 30 |
| 4 | 0 | 0 | 0 | 7 | 4 | 5 | 5 | 21 |
| 5 | 0 | 0 | 0 | 0 | 11 | 6 | 4 | 21 |
| 6 | 0 | 0 | 0 | 0 | 0 | 5 | 4 | 9 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 7 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 5 | 11 | 20 | 22 | 31 | 39 | 40 | 168 |

Block 3

| Numbers | lag + 7 | lag +6 | lag +5 | lag + 4 | lag +3 | lag +2 | lag +1 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 14 |
| 3 | 0 | 0 | 0 | 0 | 0 | 4 | 6 | 10 |
| 4 | 0 | 0 | 0 | 0 | 8 | 6 | 5 | 19 |
| 5 | 0 | 0 | 0 | 6 | 4 | 9 | 9 | 28 |
| 6 | 0 | 0 | 10 | 6 | 11 | 4 | 2 | 33 |
| 7 | 0 | 7 | 5 | 1 | 5 | 9 | 6 | 33 |
| 8 | 6 | 3 | 5 | 4 | 5 | 3 | 5 | 31 |
| Total: | 6 | 10 | 20 | 17 | 33 | 35 | 47 | 168 |

| Numbers | lag -7 | lag -6 | lag -5 | lag -4 | lag -3 | lag -2 | lag -1 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 11 | 10 | 5 | 8 | 6 | 3 | 47 |
| 2 | 0 | 2 | 2 | 2 | 3 | 10 | 9 | 28 |
| 3 | 0 | 0 | 6 | 9 | 4 | 12 | 8 | 39 |
| 4 | 0 | 0 | 0 | 2 | 7 | 4 | 7 | 20 |
| 5 | 0 | 0 | 0 | 0 | 7 | 4 | 2 | 13 |
| 6 | 0 | 0 | 0 | 0 | 0 | 5 | 6 | 11 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total | 4 | 13 | 18 | 18 | 29 | 41 | 45 | 168 |

Appendix E

*Follow Up Questionnaire Assessing Task Familiarity and Frequency of Engagement*

Date:_______________
ID number:_______________

On a scale of 1 to 7, please rate how often you have engaged in the following tasks during the past year.

1 would indicate that you have **not** engaged in the task at all, and 7 would indicate that you frequently engage in the task.

1. Wrapping a gift:

1 2 3 4 5 6 7 ____

***not engaged*** ***moderately engaged*** ***frequently engaged***

2. Smoking a cigarette:

1 2 3 4 5 6 7 ____

***not engaged*** ***moderately engaged*** ***frequently engaged***

3. Writing and mailing a letter:

1 2 3 4 5 6 7 ____

***not engaged*** ***moderately engaged*** ***frequently engaged***

Date:________________
ID number:________________

Next, on a scale of 1 to 7, please rate how familiar you feel you are with the following tasks.

1 would indicate that you are **not** familiar with the task at all, and 7 would indicate that you are very familiar with the task.

1. Wrapping a gift:

   1 2 3 4 5 6 7 ____
   ***not familiar*** ***moderately familiar*** ***very familiar***

2. Smoking a cigarette:

   1 2 3 4 5 6 7 ____
   ***not familiar*** ***moderately familiar*** ***very familiar***

3. Writing and mailing a letter:

   1 2 3 4 5 6 7 ____
   ***not familiar*** ***moderately familiar*** ***very familiar***

Appendix F

*Demographic Questionnaire*

**DEMOGRAPHIC QUESTIONNNAIRE**

**1. Date of Birth ____________________________**

**2. Age ____________________________________**

**3. GENDER (circle response) (1) MALE (2) FEMALE**

**4. HANDEDNESS (circle response) (1) LEFT (2) RIGHT (3) BOTH**

**5. IS YOUR PRIMARY LANGUAGE ENGLISH? (circle response) (1) YES**

**(2) NO**

**6. IF NO, please state the age at which you learned English and rate your proficiency on a scale of 1 to 5 (1 representing low proficiency and 5 representing excellent proficiency):**

**AGE__________**

**b. PROFICIENCY 1 2 3 4 5**

**Low Excellent**

**7. HOW MANY YEARS OF EDUCATION DO YOU HAVE AT THIS TIME?**
**(circle the response that reflects your highest level achieved)**

| 1 2 3 4 5 6 | 7 8 9 10 11 | 12 13 | 14 15 16 | 17 18 19 20 21 | 22 23 24 25 |
|---|---|---|---|---|---|
| Elementary | Secondary | Cegep | Undergrad | Graduate | Professional |

**8. PLEASE RATE YOUR HEALTH ON A SCALE OF 1 TO 5 (1 representing poor**
**health and 5 representing excellent health)**
**(circle the response that best reflects your health status)**

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Poor Health | | | | Excellent Health |

Appendix G

*Similarity Stimuli for Picture Presentations in Experiment 1b*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Very Dissimilar | Dissimilar | Neither Similar Nor Dissimilar | Similar | Very Similar |

Appendix H

Appendix H

*Matrix of Lags for Experiment 1b*

| | | Steps of Sequence[c] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Steps of Sequence[d] | 1 | - | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | 2 | 1 | - | 1 | 2 | 3 | 4 | 5 | 6 |
| | 3 | 2 | 3 | - | 1 | 2 | 3 | 4 | 5 |
| | 4 | 4 | 5 | 6 | - | 1 | 2 | 3 | 4 |
| | 5 | 7 | 8 | 9 | 10 | - | 1 | 2 | 3 |
| | 6 | 11 | 12 | 13 | 14 | 15 | - | 1 | 2 |
| | 7 | 16 | 17 | 18 | 19 | 20 | 21 | - | 1 |
| | 8 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | - |

Note: Values above the diagonal denote the lag value of the pair of pictures. Values below the diagonal denote the pairing number.

[c] These stimuli were presented on the right hand side of the screen.
[d] These stimuli were presented on the left hand side of the screen.